EXHIBIT 3

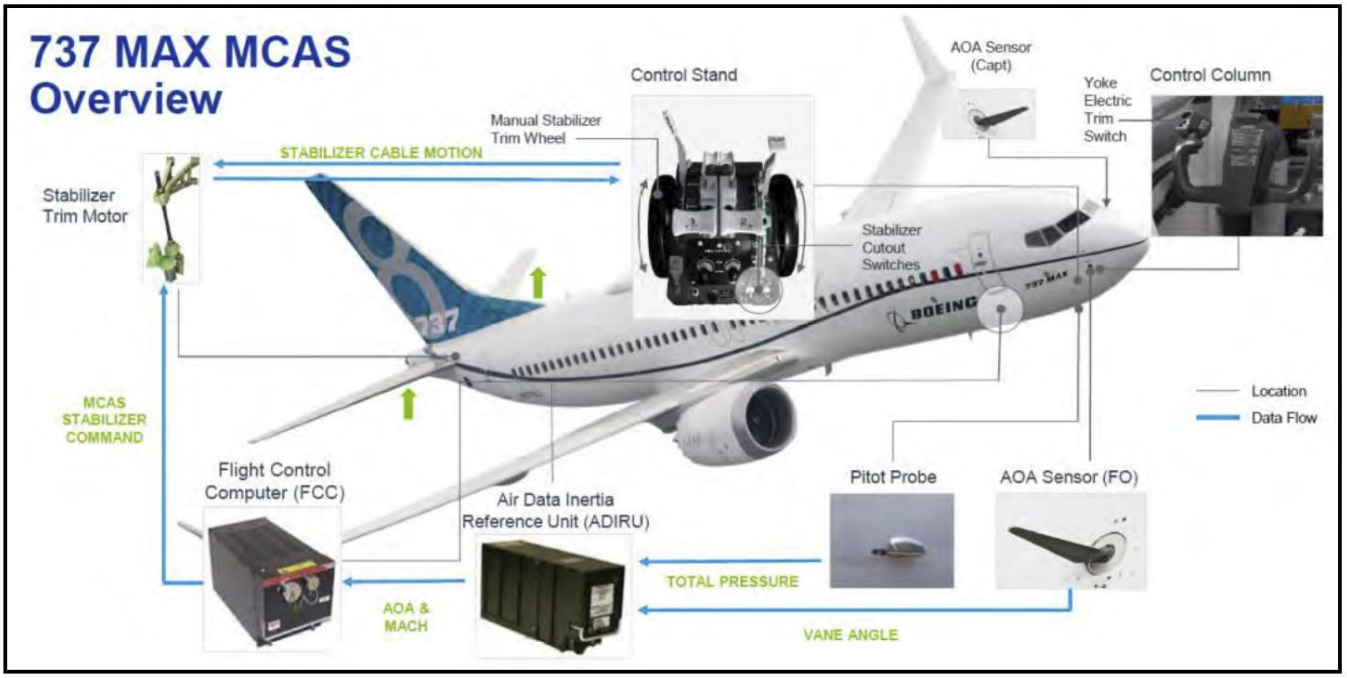
SafeR³
1709 Hopkins Street
Berkeley, CA 94707

EXPERT REPORT

DR. RUNE STORESUND, D.ENG., P.E., GE., F.ASCE, S.NAFE, D.FE

United States of America
v.
The Boeing Company
Case 4:21-cr-005-O

United States District Court for the
Northern District of Texas



March 31, 2022

Expert Report of

Rune Storesund, D.Eng., P.E., G.E., D.FE, F.ASCE, S.NAFE

United States of America v. The Boeing Company, Case No. 4:21 cr-005-O, United States District Court for the Northern District of Texas, Fort Worth Division.

Prepared for

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March 31, 2022

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Summary of Expert Opinions

My opinions are based on a review of documentation made available (as of March 31, 2022) and listed in Appendix D. While there is much information available in the public domain, not all relevant and pertinent information has been made available for my forensic work. As a result, my opinions and conclusions are made based on the publicly available evidence. Other than the "Stipulation of Facts," no formal evidence has been made available by the U.S. Department of Justice and the Boeing Corporation. Therefore, my forensic evaluations and conclusions in this report are constrained to the available information. That said, the available information is overwhelming in its support for my findings as detailed in this report. It is my hypothesis that access to additional information would only further and enrich my findings. At this time, I present the following expert opinions related to Boeing's crime of concealing MCAS to the FAA:

Opinion 1: Boeing's crime, as charged in the criminal information of conspiracy to defraud the United States, resulted in the FAA not requiring timely Level D training, which would have prevented the foreseeable erroneous MCAS activation 'but for' causative factor in the two crashes of Flight 610 on October 29, 2018 and Ethiopian Airlines Flight 302 on March 10, 2019.

Opinion 2: Development and deployment of a Level D pilot training program would have prevented the Lion Air Flight 610 (October 29, 2018) and the Ethiopian Airlines Flight 302 (March 10, 2019) crashes stemming from improper MCAS activation, as evidenced by the development and implementation of Level D pilot training across the globe starting in late 2020.

Opinion 3: The international airline industry is a highly interconnected socio-technical system where certifications and requirements from the FAA serve as a global benchmark for all private and governmental organizations, including training requirements for individual aircraft evaluated by the FAA. All the available evidence indicates both Lion Air and Ethiopian Airlines (as well as all global airlines) would have followed any Level D flight simulator training requirements the FAA ordered for U.S.-based carriers.

Opinion 4: The cost implications to responsibly ascertain the 'training differences' associated with the 737 MAX (with MCAS) was insignificant relative to the disproportionate risk that the airplane crew, victims of the two crashes, and general flying public were exposed to.

Nature of Involvement

I was retained by Paul G. Cassell to evaluate the impact on the two 737 Boeing MAX aircraft crashes (Lion Air crash Flight 610 on October 29, 2018 and Ethiopian Airlines Flight 302 on March 10, 2019) and their connection to Boeing's crime of deceiving the FAA with respect to the Maneuvering Characteristics Augmentation System (MCAS).

Qualifications

My expertise centers around quality, risk, reliability, and safety socio-technical systems. These 'socio-technical systems' are engineered systems, meaning they are an assemblage of physical components as well as human and organizational procedures that are imagined, planned, designed, constructed, operated, maintained, requalified, and decommissioned by people. Following are attributes of my personal training and experience pertinent to the fundamental principles associated with this specific engagement:

- My formal educational background includes a Bachelors of Art in Anthropology from UC Santa Cruz and a Bachelors, Masters, and Doctorate Degree in Engineered Systems from UC Berkeley. This combination of formal educational training enables me to not only understand and comprehend complex engineering, but also the human and organizational factors associated with groups, teams, and organizations.
- I have formal educational training specific to Human and Organizational Factors and their relation to Quality and Reliability of Engineered Systems. I have also personally taught and served as a Teaching Assistant specific to these concepts.
- I am a Board-Certified Forensic Engineer and a Senior Member of the National Academy of Forensic Engineers (NAFE). I am an active member, publishing peer-reviewed articles, attending and presenting topics at NAFE conferences, serving a s a peer-reviewer for the NAFE Journal, and serving as a Moderator for NAFE-1.
- I serve (since 2012) as the Executive Director for the Center for Catastrophic Risk Management (CCRM) at the University of California, Berkeley. I have been a member of that group since 2005, when it was formed in response to Human and Organizational failures stemming from the flood protection system in the greater New Orleans area. CCRM is a global group of applied researchers from academia, government and industry who have come together to develop pragmatic

solutions for the complex, multi-jurisdictional "messy" problems of the twenty-first century. CCRM conducts fundamental research on catastrophic risk through empirical data. By identifying and engaging targeted teams, whose expertise are uniquely tailored to each challenge, CCRM aims to help make the "mess" manageable.

- I am currently serving as an Adjunct Professor at Memorial University of Newfoundland where I present lectures as well as advising doctoral candidates on the subject of risk assessment and management of socio-technical systems.
- I am currently developing a risk assessment and management course for San Jose State University relative to "Resilience, Reliability, and Risk Management of Energy Systems," with an emphasis of socio-technical systems.
- I have over 8,000 hours of professional risk assessment and forensic experience relative to quality, risk, reliability, and safety socio-technical systems.
- I have over 1,000 hours of professional experience relative to 'safety culture' in socio-technical systems and am currently pioneering 'safety culture' resources for high-hazard dams based on lessons learned from the 2010 Deepwater Horizon incident in the Gulf of Mexico.
- I am currently serving as an expert in litigation that involves issues associated with an Owner/Operator and their interactions with the industry regulators (both State and Federal Regulators) relative to the performance and resulting failure, which resulted in the evacuation of almost 200,000 citizens in the matter of hours; thus have a direct and recent familiarity with the nuances associated with Regulator-based issues.
- II recently co-authored a book titled Techlash: The Future of the Socially Responsible Tech Organization, by Springer and part of the "Management, Change, Strategy, and Positive Leadership" series with coauthor Ian I. Mitroff;
- I am currently serving as a guest editor for a special issue of Safety Science titled "Managing Distributed Safety and Security in a Hyper-Connected World" that examines the impacts of increased globalization combined with modern technologies which has created a "hyper-connected" world. *Communication and commerce span multiple countries and a wide array of human and organizational cultures in minutes to hours. These hyper-connections create an environment that allows a global marketplace, where technologies are created in one part of the world and used in other parts. Many of the technologies are proprietary and considered "black boxes," meaning the ability to independently verify the purported safety of the component parts can be extremely difficult. One has to "trust" that the reported or claimed safety and security is reflective of the actual safety. The result is that safety decisions may be made in 'black box'*

conditions in one part of the world and extend un-checked to other parts of the world. Decisions made by one group are in effect imposed upon others. 'Distributed safety and security' is the consequence. In this regard, safety and security are thereby "messy" problems whose components are hard to define; solutions are unclear; major implicit and explicit value differences are paramount; contested knowledge and expertise predominate; finally, there are ill-defined and ill-understood stakeholders.

- My application of risk assessment and management spans numerous fields/disciplines. I serve as an inter-disciplinary peer reviewer on a number of journals including: Safety Science; National Academy of Forensic Engineers; Transportation Research; Remote Sensing; Ocean Engineering; Environmental Science and Technology; Marine Pollution Bulletin; American Society of Civil Engineers Journal of Geotechnical and Geoenvironmental Engineering; Hydrology and Earth System Sciences; International Journal of Disaster Risk Reduction; and Weather, Climate and Society.
- I am the CEO and Founder of NextGen Mapping, Inc., which is a software development company. As CEO of this company, I am intimately familiar with and personally engage in the development and issuance of software programs and methods. I actively employ quality programs as well as validation and testing routines to ensure minimal bias between the anticipated user experience and the actual user experience; ISSMGE International Journal of Geoengineering Case Histories
- I am developing a web-based Self-Assessment tool for Systems Crisis and Risk Assessment and Management (SCRaM). SCRaM aims to convert state of the art (as well as currently unrecognized) safety and reliability concepts to the state of the practice across high-hazard and critical infrastructure domains. These self-assessments include: Myers-Brigg Personality Types; Crisis Preparedness; Mindfulness; Safety Culture; High Reliability Organizations (HROs); as well as the ability to capture 'scenarios of concern.'

Compensation

I am providing expert services on a Pro Bono basis for this engagement.

Basis for Opinions

My opinions are based on a review of documentation made available (reviewed as of February 18, 2022). The data, analyses, and evaluations completed to formulate the presented expert forensic opinion(s) are discussed in detail below.

Opinion 1

Boeing's crime, as charged in the criminal information of conspiracy to defraud the United States, resulted in the FAA not requiring timely Level D training, which would have prevented the foreseeable erroneous MCAS activation 'but for' causative factor in the two crashes of Flight 610 on October 29, 2018 and Ethiopian Airlines Flight 302 on March 10, 2019.

Basis: Exhibit 1, Exhibit 2, Exhibit 5, Exhibit 6, Exhibit 7, Exhibit 8, Exhibit 9, Exhibit 10, Exhibit 11, Exhibit 13, Exhibit 14, Exhibit 15, Exhibit 16, Exhibit 17, Exhibit 18, Exhibit 19, Exhibit 20

Discussion: Boeing admits in the Deferred Prosecution Agreement (Exhibit 1) to committing a crime with regards to intentionally withholding information (Exhibit 5, Exhibit 6, Exhibit 7, Exhibit 8, Exhibit 9, Exhibit 10, Exhibit 11, Exhibit 13, Exhibit 14, Exhibit 15, Exhibit 16, Exhibit 17, Exhibit 18, Exhibit 19, Exhibit 20) related to MCAS, which resulted in materially false, inaccurate, and incomplete airplane manuals and pilot training. Boeing also accepts that it is responsible for acts by its officers, directors, employees, and agents (Exhibit 2). Even after the tragic crash of Lion Air in 2018, Boeing continued to conceal the MCAS, which resulted in the foreseeable and preventable Ethiopian Airlines flight 302 less than five (5) months later (Exhibit 16).

The available evidence also undoubtedly supports the conclusion that Boeing's crimes, as charged in the criminal information, created an additional and unnecessary risk to the passengers and crew on board the two flights. By intentionally withholding information related to MCAS, the materially false, inaccurate, and incomplete airplane manuals and pilot training created an environment with elevated risk in which the pilots of the two flights had to operate. This elevated risk was entirely unnecessary, because it could have easily been avoided if Boeing had not violated the law and concealed information from the FAA. By placing the passengers and crew in an environment with elevated risk, Boeing harmed the passengers and crew – being exposed to an additional and unnecessary risk is a harm.

Opinion 2

Development and deployment of a Level D pilot training program would have prevented the Lion Air Flight 610 (October 29, 2018) and the Ethiopian Airlines Flight 302 (March 10, 2019) crashes stemming from improper MCAS activation, as evidenced by the development and implementation of Level D pilot training across the globe starting in late 2020.

Basis: Exhibit 21, Exhibit 22, Exhibit 23, Exhibit 24, Exhibit 25, Exhibit 26, Exhibit 27, Exhibit 28, Exhibit 29, Exhibit 30, Exhibit 31, Exhibit 32, Exhibit 33, Exhibit 34, Exhibit 35

Discussion: Following the Lion Airlines crash in late October 2018, the Boeing Corporation issued a Flight Crew Operations Manual Bulletin for the 737 MAX (Exhibit 21, Exhibit 22) that highlighted the issue of erroneous AOA sensors and potential effects. This notice did not include training requirements or any alert as to the presence of the Maneuvering Characteristics Augmentation System (MCAS).

Months later a second tragic crash occurred on Ethiopian Airlines Flight 302. Subsequent to this second event, the fleet of 737 MAX planes were grounded and a more comprehensive examination undertaken as to fundamental design assumptions and skew between the anticipated vs actual performance of the 737 MAX. This evaluation resulted in enhanced training programs, including flight-simulator-based training for 737 MAX pilots (Exhibit 23, Exhibit 24, Exhibit 25, Exhibit 26, Exhibit 27, Exhibit 28, Exhibit 29, Exhibit 30, Exhibit 31, Exhibit 32).

The FAA performed an analysis in December of 2018 (Exhibit 33, Exhibit 34) that clearly indicated that the conditions based on the as-released 737 MAX software configuration and associated pilot training was woefully deficient and blatantly unsafe. The subsequent (post Lion Air and Ethiopian Airlines crashes) software fixes and pilot training programs have yielded the desired safety with respect to the new MCAS feature unique to the 737 MAX. Had these elements not been concealed by Boeing and provided as part of the original certification process, all the available evidence leads to the conclusion that the Lion Air Flight 610 (October 29, 2018) and the Ethiopian Airlines Flight 302 (March 10, 2019) crashes would not have occurred.

Opinion 3

The international airline industry is a highly interconnected socio-technical system where certifications and requirements from the FAA serve as a global benchmark for all private and governmental organizations, including training requirements for individual aircraft evaluated by the FAA. All the available evidence indicates both Lion Air and Ethiopian Airlines (as well as all global airlines) would have followed any Level D flight simulator training requirements the FAA ordered for U.S.-based carriers.

Basis: Exhibit 4, Exhibit 38, Exhibit 39, Exhibit 40, Exhibit 41, Exhibit 42, Exhibit 43

Discussion: There is much to be said on this particular topic. However, for the purposes of this report I will point to two elements:

1. All customers receive recommendations and instructions from the airplane manufacturer (Exhibit 38). There is no evidence either Lion Air nor Ethiopian Airlines did not follow manufacturer recommendations. Had Boeing disclosed to the FAA the full nature of MCAS, Level D-type training for pilots, all the available evidence indicates this training program would have been implemented worldwide to all 737 MAX customers.
2. The 1944 Chicago Convention (Exhibit 39, Exhibit 40, Exhibit 41) created an international community with shared aims and ideals related to international aviation. Both Ethiopia and Indonesia were signatories (Exhibit 42, Exhibit 43).

Either one of these existing mechanisms would have been sufficient by themselves to result in training recommendations by either the manufacturer (Boeing) or the FAA. This was witnessed following the training recommendations issued in late 2020.

Opinion 4

The cost implications to responsibly ascertain the 'training differences' associated with the 737 MAX (with MCAS) was insignificant relative to the disproportionate risk that the airplane crew, victims of the two crashes, and general flying public were exposed to.

Basis: Exhibit 3, Exhibit 44, Exhibit 45, Exhibit 46

Discussion: Assuming the typical cost for a new 737 MAX was on the order of $100 million per plane and pilot training was going to add an additional $1 million in cost per plane (Exhibit 3, yellow highlight), that is approximately 1% of the list price, which in many circles is considered 'budget dust.' The mere fact that this debate arose, that the configuration of the 737 MAX was ambiguous and unclear and very technical and unconservative assumptions needed to be made by Boeing illustrates the foreseeability of this safety hazard.

As of 2021, Boeing reported a total of 659 737 MAX planes delivered, out of a projected 4,000+ orders (Exhibit 44). The penalties and fines listed in the DPA amount to about $2.5 billion [1]. At a cost of $1 million per plane for training, the penalties along would have covered training for the equivalent of 2,500 737 MAX aircraft. Boeing reported a cost of approximately $5 billion in 2020 related to 737 MAX groundings [1] [2] (Exhibit 45, Exhibit 46). If we consider the total order quantity of 4,035 737 MAX planes and the aggregate cost of $7.5 billion, at a cost of $1 million per plane, the proactive training program would have totaled about $4 billion, as compared with first the loss of almost 400 lives in the Lion Air and Ethiopian Airlines crashes and second the financial costs to Boeing of approximately $7.5 billion.

While the exact cost of the training program is unspecified, it is unlikely that the unit cost of the training is completely linear and 'economies of scale' would impact the actual unit cost of more advanced simulation-based training for the 737 MAX aircraft, excluding any software enhancements and procedure updates to reduce the magnitude of the training requirement.

Reservation

This report summarizes work performed to-date and presents the findings resulting from that work. As previously mentioned, there is much information available in the public domain, not all relevant and pertinent information has been made available for my forensic work. Other than the "Stipulation of Facts," no formal evidence has been made available by the U.S. Department of Justice and the Boeing Corporation. As such, my forensic evaluations and conclusions are constrained to the available information. That said, the available information is overwhelming in its support for my findings as detailed in this report. It is my hypothesis that access to additional information would only further and enrich my findings.

I reserve the right to supplement this report and to expand or modify opinions based on review of additional material as it becomes available through ongoing discovery and/or through any additional work or review of additional work performed by others.

References

[1] Boeing Company, "The Boeing Company 2020 Annual Report," Boeing Company, 2021.

[2] B. Company, "The Boeing Company 2021 Annual Report," Boeing Corporation, 2022.

[3] U. D. o. Justice, "United States of America v. The Boeing Company, Deferred Prosecution Agreement, In the United States District Court for the Northern District of Texas," 2021.

[4] M. S. O. T. C. O. T. A. INFRASTRUCTURE, "FINAL COMMITTEE REPORT, THE DESIGN, DEVELOPMENT, AND CERTIFICATION OF TEH BOEING 737 MAX," HOUSE COMMITTEE ON TRANSPORTATION AND INFRASTRUCTURE, WASHINGTON DC, 2020.

[5] COMMITTEE ON TRANSPORTATION AND INFRASTRUCTURE, HOUSE OF REPRESENTATIVES, "THE BOEING 737 MAX: EXAMINING THE DESIGN, DEVELOPMENT, AND MARKETING OF THE AIRCRAFT, (116–40), HEARING BEFORE THE COMMITTEE ON TRANSPORTATION AND INFRASTRUCTURE, HOUSE OF REPRESENTATIVES, ONE HUNDRED SIXTEENTH CONGRESS, FIRST SESSION," U.S. GOVERNMENT PUBLISHING OFFICE, WASHINGTON DC, 2019.

[6] F. A. A. (FAA), "Summary of the FAA's Review of the Boeing 737 MAX Return to Service," Washington DC, 2020.

[7] F. A. A. (FAA), "Flight Standardization Board Report - Manufacturer - The Boeing Company - Revision 18," Federal Aviation Administration (FAA), Washington DC, 2021.

[8] F. T. A. Directorate, "Transport Airplane Risk Assessment Methodology (TARAM) Handbook," FAA, Washington DC, 2011.

[9] I. C. A. O. (ICAO), "Convention on International Civil Aviation Done At Chicago on the 7th of December 1944," Chicago, 1944.

[10] I. C. A. Organization, ICAO, [Online]. Available: https://www.icao.int/Pages/default.aspx. [Accessed 05 03 2022].

[11] N. T. S. Board, "Assumptions Used in the Safety Assessment Process and the Effects of Multiple Alerts and Indications on Pilot Performance," National Transportation Safety Board, Washington DC, 2019.

EXHIBITS

Boeing Employee-2 or members of their 737 MAX Flight Technical Team referenced and included drafts of the forthcoming 737 MAX FSB Report and airplane manuals and pilot-training materials for Boeing's 737 MAX airline customers. None of these items contained any information about MCAS, consistent with Boeing Employee-1's and Boeing Employee-2's efforts to deceive the FAA AEG into deleting information about MCAS.

The FAA AEG Published the 737 MAX FSB Report Without Any Information about MCAS and Required No Greater than "Level B" Differences Training

45. On or about July 5, 2017, the FAA AEG published the first 737 MAX FSB Report, which included the FAA AEG's "Level B" differences-training determination for the 737 MAX.

46. Because of Boeing's intentional withholding of information from the FAA AEG, the final version of the 737 MAX FSB Report lacked information about MCAS, and relevant portions of this 737 MAX FSB Report were materially false, inaccurate, and incomplete. In turn, airplane manuals and pilot-training materials for U.S.-based airlines lacked information about MCAS, and relevant portions of these manuals and materials were similarly materially false, inaccurate, and incomplete as a result.

47. After the FAA AEG published the final version of the 737 MAX FSB Report, Boeing continued to sell, and Boeing's U.S.-based airline customers were permitted to fly, the 737 MAX. Pilots flying the 737 MAX for Boeing's airline customers were not provided any information about MCAS in their airplane manuals and pilot-training materials.

Lion Air Flight 610: The First 737 MAX Crash Exposed MCAS's Operational Scope

48. On [illegible] 20[illegible] Lion Air Flight 610, a Boeing 737 MAX crashed [illegible]

Exhibit 1: Acknowledgement that Boeing delayed release of critical information related to the MCAS (Source: Deferred Prosecution Agreement, dated January 7, 2021; page 41 [3], highlights by author).

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Facts") and consents to the filing of the Information, as provided under the terms of this Agreement, in the United States District Court for the Northern District of Texas. The Fraud Section agrees to defer prosecution of the Company pursuant to the terms and conditions described below.

2. The Company admits, accepts, and acknowledges that it is responsible under United States law for the acts of its officers, directors, employees, and agents as charged in the Information, and as set forth in the Statement of Facts, and that the allegations described in the Information and the facts described in the Statement of Facts are true and accurate. The Company agrees that, effective as of the date it signs this Agreement, in any prosecution that is deferred by this Agreement, it will not dispute the Statement of Facts set forth in this Agreement, and, in any such prosecution, the Statement of Facts shall be admissible as: (a) substantive evidence offered by the government in its case-in-chief and rebuttal case; (b) impeachment evidence offered by the government on cross-examination; and (c) evidence at any sentencing hearing or other hearing. In addition, in connection therewith, the Company agrees not to assert any claim under the United States Constitution, Rule 410 of the Federal Rules of Evidence, Rule 11(f) of the Federal Rules of Criminal Procedure, Section 1B1.1(a) of the United States Sentencing Guidelines ("USSG" or "Sentencing Guidelines"), or any other federal rule that the Statement of Facts should be suppressed or is otherwise inadmissible as evidence in any form.

-2-

Exhibit 2: Boeing asserts full responsibility for the acts of all its employees, officers, directors, and agents (highlights by author) [3].

accountable for knowingly delivering aircraft with non-functioning AOA Disagree alerts to their customer airlines and failing to inform MAX pilots or the FAA that an item that was supposed to be a standard feature in the cockpit was inoperable.

737 MAX Pilot Training – ***Boeing's economic incentives led the company to a significant lack of transparency with the FAA, its customers, and 737 MAX pilots regarding pilot training requirements and negatively compromised safety.***

- Boeing had tremendous financial incentive to ensure that no regulatory determination requiring pilot simulator training for the 737 MAX was made. Under a contract signed in December 2011 with Southwest Airlines, the U.S. launch customer for the 737 MAX, Boeing was financially obligated to have discounted the price of each MAX airplane it delivered to Southwest by at least $1 million if the FAA had required simulator training for pilots transitioning from the 737 NG to the 737 MAX.[125]

- Southwest had 200 firm orders for the MAX with the option to purchase an additional 191 MAX aircraft.[126] Thus, if Boeing failed to obtain Level B (non-simulator) training requirements or less from the FAA it would have owed Southwest between $200 to nearly $400 million.[127] This helped incentivize Boeing and its leadership to forestall any simulator training for 737 MAX pilots. This had the impact of evading and averting the inclusion of at least one technology that could have affected Boeing's directive to avoid simulator training.

- In November 2012, for instance, it took a Boeing test pilot more than 10 seconds to respond to uncommanded MCAS activation during a flight simulator test, a condition the pilot found to be "catastrophic[.]"[128] The FAA has provided guidance that pilots should be able to respond to this condition within four seconds.[129] This event should have focused Boeing's attention on the need for enhanced pilot training for MAX pilots. It didn't.

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[125] See: Letter from Southwest Airlines' Drew Richardson to Chair DeFazio and Subcommittee on Aviation Chair Rick Larsen, July 26, 2019, (On file with the Committee), and David Shepardson and Tracy Rucinski, "U.S. lawmakers question Boeing's $1 mln rebate clause for Southwest 737 MAX orders," *Reuters,* October 30, 2019, accessed here: https://www.reuters.com/article/us-boeing-airplane-southwest/u-s-lawmakers-question-boeings-1-mln-rebate-clause-for-southwest-737-max-orders-idUSKBN1X92D4

[126] "Southwest Airlines Reports Fourth Quarter And Record Annual Profit; 44th Consecutive Year Of Profitability," Southwest Airlines Company, January 26, 2017, accessed here: http://www.southwestairlinesinvestorrelations.com/tools/viewpdf.aspx?page={55E44CBF-22E3-41F5-84EF-B3EDAB030B07}

[127] In January 2017, Southwest had 200 firm 737 MAX orders with the option to purchase 191 additional MAX aircraft. In October 2019, one year after the Lion Air crash, Southwest had 246 firm MAX orders, 34 of its MAX aircraft were grounded and it had the option to purchase 115 additional MAX aircraft. See: "Southwest Airlines Reports Fourth Quarter And Record Annual Profit; 44th Consecutive Year Of Profitability," Southwest Airlines Company, January 26, 2017, accessed here: http://www.southwestairlinesinvestorrelations.com/tools/viewpdf.aspx?page={55E44CBF-22E3-41F5-84EF-B3EDAB030B07}; "Southwest Corporate Fact Sheet," Southwest Airlines Company, 2020, accessed here: https://www.swamedia.com/pages/corporate-fact-sheet#fleet and "Southwest Reports Record Third Quarter Net Income And Earnings Per Share," Southwest Airlines Company, October 24, 2019, accessed here: http://www.southwestairlinesinvestorrelations.com/news-and-events/news-releases/2019/10-24-2019-112936719

[128] Internal email from Boeing engineer to two Boeing test pilots, "Subject: MCAS Hazard Assessment," Sent: November 1, 2012, 2:40 PM, BATES Number TBC T&I 131226 – 131227 (On file with the Committee).

[129] See: JATR Report p.14 and FAA Advisory Circular 25.1329-1C, October 27, 2014, p. 78, accessed here: https://www.faa.gov/documentLibrary/media/Advisory_Circular/AC_25_1329-1C.pdf

Exhibit 3: Obligation of Boeing to pay $1 million if simulator training was required (highlights by author) [4].

-FINAL COMMITTEE REPORT: BOEING 737 MAX-
2. Executive Summary

Addressing the qualifications of these pilots at a June 2019 Subcommittee on Aviation hearing, Captain Dan Carey, a 35-year career pilot and then president of the Allied Pilots Association, which represents 15,000 American Airlines pilots, said in his written statement:

> To make the claim that these accidents would not happen to U.S.-trained pilots is presumptuous and not supported by fact. Vilifying non-U.S. pilots is disrespectful and not solution-based, nor is it in line with a sorely needed global safety culture that delivers one standard of safety and training. Simply put, Boeing does not produce aircraft for U.S. pilots vs. pilots from the rest of the world.[53]

Retired airline captain Chesley B. "Sully" Sullenberger III, who landed U.S. Airways flight 1549 on the Hudson River in 2009 saving all 155 people on board in what came to be known as the "Miracle on the Hudson," also testified at that hearing. He offered similar sentiments about the qualifications of these pilots as part of his remarks about the two crashes.[54] In his prepared testimony Captain Sullenberger wrote:

> These crashes are demonstrable evidence that our current system of aircraft design and certification has failed us… It is obvious that grave errors were made that have had grave consequences, claiming 346 lives… Accidents are the end result of a causal chain of events, and in the case of the Boeing 737 MAX, the chain began with decisions that had been made years before, to update a half-century-old design… We owe it to everyone who flies, passengers and crews alike, to do much better than to design aircraft with inherent flaws that we intend pilots will have to compensate for and overcome. Pilots must be able to handle an unexpected emergency and still keep their passengers and crew safe, but we should first design aircraft for them to fly that do not have inadvertent traps set for them.[55]

For two brand-new airplanes, of a brand-new derivative model, to crash within five months of each other was extraordinary given significant advances in aviation safety over the last two decades.[56] While certain facts and circumstances surrounding the accidents differed, a common

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[53] Prepared statement of Captain Daniel F. Carey, President, Allied Pilots Association, Hearing titled, "Status of the Boeing 737 MAX: Stakeholder Perspectives," Subcommittee on Aviation of the Committee on Transportation and Infrastructure, U.S. House of Representatives, 116th Congress, First Session, June 19, 2019, accessed here: https://transportation.house.gov/imo/media/doc/CA%20Carey%20Hearing%20testimony%20.pdf

[54] Robert D. McFadden, "Pilot Is Hailed After Jetliner's Icy Plunge," *New York Times*, January 15, 2009, accessed here: https://www.nytimes.com/2009/01/16/nyregion/16crash.html and Hearing titled, "Status of the Boeing 737 MAX: Stakeholder Perspectives," Subcommittee on Aviation, Committee on Transportation and Infrastructure, U.S. House of Representatives, 116th Congress, First Session, June 19, 2019, accessed here: https://transportation.house.gov/committee-activity/hearings/status-of-the-boeing-737-max-stakeholder-perspectives

[55] Prepared statement of Chesley B. "Sully" Sullenberger III, Hearing titled, "Status of the Boeing 737 MAX: Stakeholder Perspectives," Subcommittee on Aviation of the Committee on Transportation and Infrastructure, U.S. House of Representatives, 116th Congress, First Session, June 19, 2019, accessed here: https://transportation.house.gov/imo/media/doc/Sully%20Sullenberger%20Testimony.pdf

[56] See: "Fact Sheet – Out Front on Airline Safety: Two Decades of Continuous Evolution," Federal Aviation Administration, August 2, 2018, accessed here: https://www.faa.gov/news/fact_sheets/news_story.cfm?newsId=22975; "Safety Record of U.S. Air Carriers," Airlines for America, accessed here: https://www.airlines.org/dataset/safety-

Exhibit 4: Testimony to the House Committee related to pilot training [4].

slowing the 737 MAX production line. The Committee's investigation has identified several instances where the desire to meet these goals and expectations jeopardized the safety of the flying public.

2) Faulty Design and Performance Assumptions. Boeing made fundamentally faulty assumptions about critical technologies on the 737 MAX, most notably with MCAS. Based on these faulty assumptions, Boeing permitted MCAS—software designed to automatically push the airplane's nose down in certain conditions—to activate on input from a single angle of attack (AOA) sensor. It also expected that pilots, who were largely unaware that the system existed, would be able to mitigate any potential malfunction. Boeing also failed to classify MCAS as a safety-critical system, which would have attracted greater FAA scrutiny during the certification process. The operation of MCAS also violated Boeing's own internal design guidelines related to the 737 MAX's development which stated that the system should "not have any objectionable interaction with the piloting of the airplane" and "not interfere with dive recovery."[62]

3) Culture of Concealment. In several critical instances, Boeing withheld crucial information from the FAA, its customers, and 737 MAX pilots. This included concealing the very existence of MCAS from 737 MAX pilots[63] and failing to disclose that the AOA Disagree alert was inoperable on the vast majority of the 737 MAX fleet,[64] despite having been certified as a standard aircraft feature.[65] The AOA Disagree alert is intended to notify the crew if the aircraft's two AOA sensor readings disagree, an event that can occur if one sensor is malfunctioning or providing faulty AOA data. Boeing not only concealed this information from both the FAA and pilots, but also continued to deliver MAX aircraft to its customers knowing that the AOA Disagree alert was inoperable on most of these aircraft. Further, Boeing concealed internal test data it had that revealed it took a Boeing test pilot more than 10 seconds to diagnose and respond to uncommanded MCAS activation[66] in a flight simulator, a condition the pilot found to be "catastrophic[.]"[67] While it was not required to share this information with the FAA or Boeing customers, it is inconceivable and inexcusable that

[62] Boeing Coordination Sheet, Revision G, June 11, 2018, TBC-T&I 30584 – 30592 at TBC-T&I 30588, at p. 170, accessed here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg38282/pdf/CHRG-116hhrg38282.pdf
[63] Benjamin Shang, "Boeing's CEO explains why the company didn't tell 737 Max pilots about the software system that contributed to 2 fatal crashes," *Business Insider*, April 29, 2019, accessed here: https://www.businessinsider.com/boeings-ceo-on-why-737-max-pilots-not-told-of-mcas-2019-4
[64] Alan Levin, "Boeing Failure to Fix 737 Max Warning Light May Draw FAA Penalty," *Bloomberg*, February 21, 2020, accessed here: https://www.bloomberg.com/news/articles/2020-02-21/boeing-failure-to-fix-737-max-cockpit-light-may-draw-faa-penalty
[65] See: Letter from then-Acting FAA Administrator Dan Elwell to Chair Peter DeFazio, July 11, 2019, (On file with the Committee), and Julie Johnsson, Ryan Beene and Mary Schlangenstein, "Boeing Held Off for Months on Disclosing Faulty Alert on 737 Max," *Bloomberg*, May 5, 2019, accessed here: https://www.bloomberg.com/news/articles/2019-05-05/boeing-left-airlines-faa-in-dark-on-737-alert-linked-to-crash
[66] The Maneuvering Characteristics Augmentation System (MCAS) was designed to activate automatically without any pilot command. To the extent this report uses the term "uncommanded" in connection with MCAS activation, it is for consistency with Boeing's own Functional Hazard Assessments which measured "Uncommanded MCAS function operation to pilot reaction[,]" and determined that a pilot reaction time of greater than 10 seconds could be "catastrophic[.]"
[67] "Coordination Sheet, Subject: 737 MAX Flaps Up High Alpha Stabilizer Trim (MCAS) Requirements," No. Aero-B-BBA8-C12-0159, Model: 737-MAX (-7/8/9), Revision D, March 30, 2016, BATES Number TBC-T&I 29160 – 29166 at p. 164, accessed here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg38282/pdf/CHRG-116hhrg38282.pdf

Exhibit 5: House Committee finding of "faulty design and performance assumptions" as well as "culture of concealment" [4].

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- In 2013, a Boeing engineer raised the issue of installing on the 737 MAX a synthetic airspeed indicator—a computer-based indicator of speed that can be compared to actual airspeed measures—as had been done on the 787 Dreamliner. However, this request was rejected by Boeing management due to cost concerns and because adding synthetic airspeed could have jeopardized the 737 MAX program's directive to avoid pilot simulator training requirements.[84]

- The Committee has learned that to thank him for keeping to the MAX's production schedule, Boeing gave Michael Teal, the former Chief Project Engineer on the 737 MAX program, restricted stock options after the airplane's first flight in 2016 to show its appreciation for his work.[85]

- In June 2018, Ed Pierson, a senior Boeing plant supervisor at the company's Renton, Washington 737 MAX production factory, emailed Scott Campbell, the 737 General Manager, requesting a meeting about "safety concerns."[86] Mr. Pierson described multiple concerns about production and schedule pressures that were impacting quality control and safety issues. "As a retired Naval Officer and former Squadron Commanding Officer," wrote Pierson, "I know how dangerous even the smallest of defects can be to the safety of an airplane. Frankly right now all my internal warning bells are going off. And for the first time in my life, I'm sorry to say that I'm hesitant about putting my family on a Boeing airplane."[87]

- In July 2018, five weeks after Mr. Pierson's email, he finally met with Mr. Campbell in Mr. Campbell's office. According to Mr. Pierson's testimony to the Committee, he told Mr. Campbell that in the military they would temporarily halt production if they had the kinds of safety problems that Mr. Pierson was seeing on the MAX factory floor. Mr. Campbell allegedly responded: "The military is not a profit-making organization."[88] Rather than heeding Mr. Pierson's dire warnings and thoroughly evaluating his safety concerns, Boeing continued to ramp up production on the 737 MAX[89] and rehired retired Boeing employees

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[84] See: Boeing internal emails, "Subject: Synthetic Airspeed," February 26, 2013, at p. 1, accessed here: https://transportation.house.gov/imo/media/doc/Compressed%20Updated%202020.01.09%20Boeing%20Production.pdf, Natalie Kitroeff, David Gelles and Jack Nicas, "Boeing 737 Max Safety System Was Vetoed, Engineer Says," *New York Times*, October 2, 2019, (Updated 29, 2019), accessed here: https://www.nytimes.com/2019/10/02/business/boeing-737-max-crashes.html and Dominic Gates, Steve Miletich and Lewis Kamb, "Boeing rejected 737 MAX safety upgrades before fatal crashes, whistleblower says," *Seattle Times*, October 2, 2019 (Updated October 3, 2019), accessed here: https://www.seattletimes.com/business/boeing-aerospace/boeing-whistleblowers-complaint-says-737-max-safety-upgrades-were-rejected-over-cost

[85] Committee staff interview of Michael Teal, former Vice President, Chief Project Engineer and Deputy Program Manager of the 737 MAX Program, Boeing Commercial Airplanes, May 11, 2020, accessed here: https://transportation.house.gov/committee-activity/boeing-737-max-investigation

[86] Email from Ed Pierson to Scott A. Campbell, "Subject: Recovery Operations & Safety Concerns," Saturday, June 9, 2018 1:32 PM.

[87] Ibid.

[88] Hearing titled, "The Boeing 737 MAX: Examining the Federal Aviation Administration's Oversight of the Aircraft's Certification," House Committee on Transportation and Infrastructure, 116th Congress, First Session, U.S. House of Representatives, December 11, 2019, accessed here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg40697/pdf/CHRG-116hhrg40697.pdf

[89] The Boeing Company, Q2 2018 Earnings Call, July 25, 2018, p. 6, accessed here: https://s2.q4cdn.com/661678649/files/doc_financials/quarterly/2018/q2/2Q18-Earnings-Call-Transcript-Final.pdf

Exhibit 6: Illustrations of 'warning' dismissed by Boeing management [4] (highlights by author).

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to keep the production lines moving at the Renton plant.[90] Lion Air flight 610 crashed three months later in October 2018.

Maneuvering Characteristics Augmentation System (MCAS) – *Boeing failed to appropriately classify MCAS as a safety-critical system, concealed critical information about MCAS from pilots, and sought to diminish focus on MCAS as a "new function" in order to avoid increased costs, and "greater certification and training impact."*

- Both Boeing and the FAA failed to appropriately designate MCAS a safety-critical system. In May 2019, then-Acting FAA Administrator Dan Elwell acknowledged this point at a hearing before the Committee.[91]

- In 2012, Boeing developed initial concepts for an MCAS annunciator to inform pilots when MCAS failed to activate, but never implemented it.[92] Instead, Boeing designed the "speed trim fail" alert to incorporate the MCAS failure functionality.[93] Human factors experts have argued that an MCAS-specific display that went beyond just indicating MCAS's "failure" could have helped to negate pilot confusion in the MAX accidents.[94]

- In June 2013, Boeing employees formulated a plan to help avoid increased "cost,"[95] and "greater certification and training impact" for the 737 MAX by describing MCAS as "an addition to [the existing] Speed Trim [system]."[96] The Boeing meeting minutes warned: "If we emphasize MCAS is a new function there may be a greater certification and training

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[90] "Boeing 737 MAX: Retired former employees come back to help with production," *Traveller*, September 12, 2018, accessed here: https://www.traveller.com.au/boeing-737-max-retired-former-employees-come-back-to-help-with-production-h157in

[91] Hearing titled, "Status of the Boeing 737 MAX: Stakeholder Perspectives," Subcommittee on Aviation, Committee on Transportation and Infrastructure, U.S. House of Representatives, 116th Congress, First Session, May 15, 2019, pp. 28-29, accessed here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg37277/pdf/CHRG-116hhrg37277.pdf

[92] "Preliminary Design Decision Memo," High Speed Pitch-Up, Revision A, November 8, 2012, BATES Number TBC-T&I 010920, TBC-T&I 010926, accessed at p. 119 here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg38282/pdf/CHRG-116hhrg38282.pdf

[93] Hearing titled, "The Boeing 737 MAX: Examining the Design, Development, and Marketing of the Aircraft," Committee on Transportation and Infrastructure, U.S. House of Representatives, 116th Congress, First Session, October 30, 2019, p. 20, accessed here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg38282/pdf/CHRG-116hhrg38282.pdf

[94] Dr. Mica Endsley, a Committee Chair at the Human Factors and Ergonomics Society and a former Chief Scientist of the U.S. Air Force testified before the Transportation and Infrastructure Committee in December 2019. She pointed out: "It is critical that the automation mode and status be clearly and saliently displayed. In this case a display showing that the MCAS was on and each time it engaged, as well as its effect on aircraft trim, would have provided key input to the pilots as to what the system was doing. If the MCAS is overridden by the pilot and turned off, this should be displayed as well to provide clear feedback to the pilots on its state." See: Dr. Mica R. Endsley, Prepared Testimony, "The Boeing 737 MAX: Examining the Federal Aviation Administration's Oversight of the Aircraft's Certification," Committee on Transportation and Infrastructure, U.S. House of Representatives, 116th Congress, First Session, December 11, 2019, accessed here: https://transportation.house.gov/committee-activity/hearings/the-boeing-737-max-examining-the-federal-aviation-administrations-oversight-of-the-aircrafts-certification

[95] Boeing ITRACS Item, "MCAS/Speed Trim," 37MAXFCI-PDR AI22, BATES Number TBC T&I 549172-549173. (On file with the Committee).

[96] Boeing internal email, "Subject: PRG – 37MAXFCI-PDR_AI22 – MCAS/Speed Trim," June 7, 2013, at p. 93, accessed here: https://transportation.house.gov/imo/media/doc/Compressed%20Updated%202020.01.09%20Boeing%20Production.pdf

Exhibit 7: House Committee determination of Boeing concealing information [4].

impact."[97] According to the email that summarized the meeting minutes, a Boeing AR concurred with this plan.[98]

- In 2015, a Boeing AR raised the question of whether MCAS was "vulnerable to single AOA sensor failures…."[99] Despite this, the aircraft was delivered with MCAS dependent on a single AOA sensor. Boeing's decision to allow MCAS to operate off of a single AOA sensor has been roundly criticized by a wide range of aviation safety experts.[100]

- In March 2016, the General Manager of Boeing's 737 MAX program, Keith Leverkuhn, and Michael Teal, the former Chief Project Engineer on the 737 MAX program, both approved a redesign of MCAS to increase its authority to move the aircraft's stabilizer at low speed, in order to address "stall characteristics" requirements necessary for FAA certification.[101]

- Just hours after the approval for MCAS's redesign was granted, Boeing sought, and the FAA approved, the removal of references to MCAS from Boeing's Flight Crew Operations Manual (FCOM)[102]—a document that provides procedures, performance, and systems information to flight crews to enable their safe and efficient operation of the airplane.[103] As a result, 737 MAX pilots were precluded from knowing of the existence of MCAS and its potential effect on aircraft handling without pilot command. Meanwhile, the FAA officials who authorized this request remained unaware of the redesign of MCAS until **after** the crash of the Lion Air flight. Although Boeing's approval of the redesign of MCAS and its efforts to remove references to MCAS from pilot training material occurred nearly simultaneously it is unclear if these actions were coordinated.

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[97] Ibid.
[98] Ibid. (The issue regarding this June 2013 meeting, and Boeing's response to it, are discussed at length in the *MCAS section* of this report.)
[99] See Boeing internal email, AOA Sensor email string – TBC-T&I 10584-10585, December 17, 2015, p. 121, accessed here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg38282/pdf/CHRG-116hhrg38282.pdf
[100] See: Peter Cohan, "MIT Expert Highlights 'Divergent Condition' Caused By 737 MAX Engine Placement," *Forbes*, April 2, 2019, accessed here: https://www.forbes.com/sites/petercohan/2019/04/02/mit-expert-highlights-divergent-condition-caused-by-737-max-engine-placement/#7c4f24d040aa; Jack Nicas, Natalie Kitroeff, David Gelles, & James Glanz, "Boeing Built Deadly Assumptions Into 737 Max, Blind to a Late Design Change," *New York Times*, June 1, 2019, accessed here: https://www.nytimes.com/2019/06/01/business/boeing-737-max-crash.html?searchResultPosition=1; and Gregory Travis, "How the Boeing 737 Max Disaster Looks to a Software Developer," *IEEE Spectrum*, April 18, 2019, accessed here: https://spectrum.ieee.org/aerospace/aviation/how-the-boeing-737-max-disaster-looks-to-a-software-developer
[101] See: Boeing presentation, "737 MAX: SMYD (EPS) & FCC (MCAS) FT Validation, Basic Stall Characteristics," Compilation of previous presentations S&C, April 7, 2016, BATES Number TBC T&I 257428-257439, at TBC T&I 257430 (On file with Committee); Boeing presentation, "737 MAX / Stall Characteristics – Mitigation," Aero S&C, March 30, 2016, BATES Number TBC T&I 046618-046682 (On file with the Committee); and Boeing internal email, "Subject: FW: 737MAX Stall Chars Meeting Summary 3-30-16," Sent: March 30, 2016, 12:46:55 PM, BATES Number TBC T&I 257421-257422 (On file with the Committee). See also, Committee staff transcribed interview of Keith Leverkuhn, former Vice President and General Manager of the 737 MAX program, Boeing Commercial Airplanes, May 19, 2020 and Committee staff interview of Michael Teal, former Vice President, Chief Project Engineer and Deputy Program Manager of the 737 MAX Program, Boeing Commercial Airplanes, May 11, 2020.
[102] Email from Mark Forkner to FAA, "Subject: MCAS lives in both FCCs," Sent: March 30, 2016 11:16:45 (On file with the Committee).
[103] "Development of Aircraft Operating Manuals," SKYbrary, accessed here: https://www.skybrary.aero/index.php/Development_of_Aircraft_Operating_Manuals

Exhibit 8: Additional examples of concealment by Boeing [4].

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- After Boeing redesigned MCAS in 2016 to increase its authority to move the aircraft's stabilizer at lower speeds, Boeing failed to reevaluate the system or perform single- or multiple-failure analyses of MCAS.[104]

- In June 2016, a Boeing AR raised concerns following a test flight of the 737 MAX during which MCAS countered the pilot's attempts to trim the airplane, including concerns related to the vulnerability caused by faulty AOA readings.[105] These concerns were discounted by the AR's Boeing colleagues, particularly Boeing's test pilots.[106] However, faulty AOA data that resulted in uncommanded MCAS activation was a significant contributing factor in the crashes of both the Lion Air and Ethiopian Airlines flights.[107]

- Following the same test flight, another Boeing engineer asked if repetitive MCAS activation was a safety issue.[108] A colleague responded: "I don't think this is safety, other then (sic) the pilot could fight the MCAS input and over time find themselves in a large mistrim."[109] In both the Lion Air and Ethiopian Airlines flights, the pilots struggled to overcome MCAS, partly because of MCAS's repetitive activations that forced the airplanes into a nose-down configuration from which the pilots were unable to recover.[110]

- In a transcribed interview with Committee staff, Michael Teal, the former Chief Project Engineer on the 737 MAX program, acknowledged that when he approved the MCAS redesign in March 2016 he was unaware: 1) that MCAS operated from a single AOA sensor, 2) that MCAS could activate repeatedly, or 3) that Boeing had internal test data showing that one of its own test pilots took more than 10 seconds to react to uncommanded MCAS activation in a flight simulator, and described the results as "catastrophic."[111]

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[104] See Boeing presentation to FAA, "MCAS Development and Certification Overview," December 17, 2018, (updated and transmitted to FAA on March 1, 2019), TBC-T&I130073, TBC-T&I130111, pp. 178 - 201 at p. 198, accessed here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg38282/pdf/CHRG-116hhrg38282.pdf

[105] Boeing internal email, "Subject: RE: S&C Brief Summary: 1A001, Test 009-25 6/13/16 [BLOCK 2]," Sent: Wednesday, June 15, 2016, 10:23 AM, BATES Number TBC-T&I 246488 – TBC-T&I 246493 at TBC-T&I 246490 and Boeing internal email, "Subject: RE: S&C Brief Summary: 1A001, Test 009-25 6/13/16 [BLOCK 2]," Sent: Wednesday, June 15, 2016, 1:01 PM, BATES Number TBC-T&I 246488 – TBC-T&I 246493 at TBC-T&I 246489.

[106] Boeing internal email, "Subject: RE: S&C Brief Summary: 1A001, Test 009-25 6/13/16 [BLOCK 2]," Sent: Wednesday, June 15, 2016, 1:43 PM, BATES Number TBC-T&I 246488 – 246493 at TBC-T&I 246489 and Boeing internal email, "Subject: RE: Discussion of MCAS Characteristics," Sent: June 22, 2016, 1:59 PM, BATES Number TBC-T&I 292457 – 292458. (On file with the Committee).

[107] See: "Lion Air Flight 610 Final Aircraft Accident Investigation Report," accessed here: https://aviation-is.better-than.tv/737%20MAX%202018%20-%20035%20-%20PK-LQP%20Final%20Report.pdf and "Ethiopian Airlines Flight 302 Interim Investigation Report," accessed here: http://www.aib.gov.et/wp-content/uploads/2020/documents/accident/ET-302%20%20Interim%20Investigation%20%20Report%20March%209%202020.pdf

[108] Boeing internal email, "Subject: RE: Squawk for MCAS trim Event," Sent: Thursday, June 16, 2016, 2:49 PM, BATES Number TBC-T&I 220826 (On file with the Committee).

[109] Boeing internal email, "Subject: RE: Squawk for MCAS trim Event," Sent: June 20, 2016, 6:38:08 AM, BATES Number TBC-T&I 220826 (On file with the Committee).

[110] See: "Lion Air Flight 610 Final Aircraft Accident Investigation Report," accessed here: https://aviation-is.better-than.tv/737%20MAX%202018%20-%20035%20-%20PK-LQP%20Final%20Report.pdf and "Ethiopian Airlines Flight 302 Interim Investigation Report," accessed here: http://www.aib.gov.et/wp-content/uploads/2020/documents/accident/ET-302%20%20Interim%20Investigation%20%20Report%20March%209%202020.pdf

[111] Committee staff interview of Michael Teal, former Vice President, Chief Project Engineer and Deputy Program Manager of the 737 MAX Program, Boeing Commercial Airplanes, May 11, 2020.

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Exhibit 9: Additional examples of concealment by Boeing [1].

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- Mr. Teal defended his lack of awareness of these key attributes on a system he approved saying he relied on the advice of the engineers on the MAX program. Although Mr. Teal was the program's Chief Project Engineer responsible for signing off and approving of key design decisions on the MAX, he did not actually supervise any engineers. "[Y]ou could say that none of them worked for me but all of them worked for me," he said.[112] This reporting structure contributed to an overall lack of accountability on the MAX program.

- The operating parameters of the MCAS system eventually placed on the 737 MAX aircraft violated Boeing's own internal design requirements which demanded that MCAS "not have any objectionable interaction with the piloting of the airplane" and "not interfere with dive recovery," which occurred in both 737 MAX crashes.[113]

AOA Disagree Alert – ***Boeing concealed information from the FAA, its customers, and pilots that the AOA Disagree alerts were inoperable on most of the 737 MAX fleet, despite their operation being "mandatory" on all 737 MAX aircraft. To date, FAA has failed to hold Boeing accountable for these actions.***

- Boeing has publicly blamed its software supplier for an issue that tied the AOA Disagree alert, which was supposed to be standard on all 737 MAX aircraft, to an optional AOA Indicator display,[114] the result of which was to render the AOA Disagree alert inoperable on more than 80 percent of the MAX aircraft. However, the Committee has learned that in July 2015, Boeing tested this software and failed to detect the problem.[115]

- In August 2017, five months after the 737 MAX was certified by the FAA and three months after it entered revenue service, Boeing issued a problem report to its supplier complaining that the 737 MAX's AOA Disagree alert was tied to the optional AOA Indicator and therefore was not functioning on the vast majority of the 737 MAX fleet worldwide.[116] Yet Boeing had previously approved of the version of the software that tied the AOA Disagree alert to the optional AOA Indicator display in July 2015.[117]

- Rather than immediately informing the FAA and Boeing customers about this issue when it was discovered in August 2017, and advising Boeing to fix the problem via a software update as soon as possible, a Boeing AR consented to Boeing's plan to postpone the software

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[112] Ibid.
[113] Boeing Coordination Sheet, Revision G, June 11, 2018, TBC-T&I 30584 – 30592 at TBC-T&I 30588, at p. 170, accessed here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg38282/pdf/CHRG-116hhrg38282.pdf.
[114] "Boeing Statement on AOA Disagree Alert," Press Release, The Boeing Company, May 5, 2019, accessed here: https://boeing.mediaroom.com/news-releases-statements?item=130431
[115] "AOA DISAGREE Displayed with AOA Fail Flag," Problem Report (PR) 195, PR opened: May 14, 2015, PR closed: July 29, 2015, BATES Number TBC T&I TBC 267345-267346. (On file with the Committee). (Hereafter referred to as "AOA Disagree Alert Problem Report #195").
[116] See: Boeing AOA Disagree Alert Narrative. TBC-T&I 267826 – TBC-T&I 267833, at TBC-T&I 267830 (On file with the Committee). and Alan Levin, "Boeing Failure to Fix 737 MAX Warning Light May Draw FAA Penalty," *Bloomberg*, February 21, 2020, accessed here: https://www.bloomberg.com/news/articles/2020-02-21/boeing-failure-to-fix-737-max-cockpit-light-may-draw-faa-penalty
[117] Letter to Chair DeFazio and Subcommittee on Aviation Chair Larsen from attorney for Rockwell Collins, June 20, 2019, p. 9. (On file with the Committee).

Exhibit 10: Additional examples of concealment by Boeing [1].

update until 2020, three years later, so it could be done in conjunction with the rollout of Boeing's planned 737 MAX-10 aircraft.[118]

- Although Boeing prepared a "Fleet Team Digest" to inform its customers about the inoperable AOA Disagree alert, Boeing never sent it, keeping Boeing's customers in the dark about the inoperable alert until **after** the Lion Air crash.[119]

- Boeing's software supplier, Collins Aerospace, also falsely believed that Boeing had communicated the AOA Disagree alert issue to its 737 MAX customers.[120]

- Boeing provided Lion Air with a Flight Crew Operations Manual (FCOM) for its 737-8 MAX aircraft dated August 16, 2018, one year after learning that the AOA Disagree alert was not functioning on most 737 MAX aircraft, including those operated by Lion Air. The FCOM explained how the AOA Disagree alert was intended to work and provided absolutely no indication that Boeing was fully aware that the AOA Disagree alert on the Lion Air 737 MAX aircraft was not operational.[121] As a result, Lion Air pilots who referenced Boeing's FCOM would have falsely believed that the AOA Disagree alert was functioning properly and would reliably warn them of a malfunctioning AOA sensor. Boeing knowingly deceived these pilots and its customer airlines.

- Boeing did not acknowledge that the AOA Disagree alerts on more than 80 percent of the 737 MAX fleet were inoperative until **after** the Lion Air crash in October 2018.[122]

- By the time of the Lion Air crash, Boeing had knowingly delivered approximately 200 MAX aircraft to customers around the world with non-functioning AOA Disagree alerts.[123]

- In July 2019, then-Acting FAA Administrator Dan Elwell informed the Committee that "[a]lthough an AOA Disagree message was not necessary to meet FAA safety regulations, once it was made part of the approved type design, it was required to be installed and functional on all 737 MAX airplanes Boeing produced."[124]

- Although the AOA Disagree alert was not considered a safety critical component, Boeing knowingly delivered 737 MAX aircraft to its customers with inoperable AOA Disagree alerts that did not conform to the airplane's amended type certificate. As far as the Committee understands, the FAA has failed to take any measures whatsoever to hold Boeing

[118] Boeing AOA Disagree Alert Narrative, TBC-T&I 267826 – TBC-T&I 267833, at TBC-T&I 267830 - TBC-T&I 267831. (On file with the Committee).
[119] Boeing AOA Disagree Alert Narrative, TBC-T&I 267826 – TBC-T&I 267833, at TBC-T&I 267831. (On file with the Committee).
[120] Committee staff interview with Rockwell Collins employee, September 11, 2019.
[121] Lion Air Flight Crew Operations Manual, August 16, 2018, accessed at pp. 175-177 here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg38282/pdf/CHRG-116hhrg38282.pdf
[122] Alan Levin, "Boeing Failure to Fix 737 MAX Warning Light May Draw FAA Penalty," *Bloomberg*, February 21, 2020, accessed here: https://www.bloomberg.com/news/articles/2020-02-21/boeing-failure-to-fix-737-max-cockpit-light-may-draw-faa-penalty
[123] "737 MAX: Deliveries Report," The Boeing Company, accessed here: http://www.boeing.com/commercial/#/orders-deliveries
[124] Letter from then-Acting FAA Administrator Dan Elwell to Chair Peter DeFazio, regarding the mandatory installation of functional AOA Disagree alerts on all Boeing 737 MAX aircraft, July 11, 2019. (On file with the Committee).

Exhibit 11: Additional examples of concealment by Boeing [1].

to keep the production lines moving at the Renton plant.[90] Lion Air flight 610 crashed three months later in October 2018.

Maneuvering Characteristics Augmentation System (MCAS) – *Boeing failed to appropriately classify MCAS as a safety-critical system, concealed critical information about MCAS from pilots, and sought to diminish focus on MCAS as a "new function" in order to avoid increased costs, and "greater certification and training impact."*

- Both Boeing and the FAA failed to appropriately designate MCAS a safety-critical system. In May 2019, then-Acting FAA Administrator Dan Elwell acknowledged this point at a hearing before the Committee.[91]

- In 2012, Boeing developed initial concepts for an MCAS annunciator to inform pilots when MCAS failed to activate, but never implemented it.[92] Instead, Boeing designed the "speed trim fail" alert to incorporate the MCAS failure functionality.[93] Human factors experts have argued that an MCAS-specific display that went beyond just indicating MCAS's "failure" could have helped to negate pilot confusion in the MAX accidents.[94]

- In June 2013, Boeing employees formulated a plan to help avoid increased "cost,"[95] and "greater certification and training impact" for the 737 MAX by describing MCAS as "an addition to [the existing] Speed Trim [system]."[96] The Boeing meeting minutes warned: "If we emphasize MCAS is a new function there may be a greater certification and training

[90] "Boeing 737 MAX: Retired former employees come back to help with production," *Traveller*, September 12, 2018, accessed here: https://www.traveller.com.au/boeing-737-max-retired-former-employees-come-back-to-help-with-production-h157in

[91] Hearing titled, "Status of the Boeing 737 MAX: Stakeholder Perspectives," Subcommittee on Aviation, Committee on Transportation and Infrastructure, U.S. House of Representatives, 116th Congress, First Session, May 15, 2019, pp. 28-29, accessed here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg37277/pdf/CHRG-116hhrg37277.pdf

[92] "Preliminary Design Decision Memo," High Speed Pitch-Up, Revision A, November 8, 2012, BATES Number TBC-T&I 010920, TBC-T&I 010926, accessed at p. 119 here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg38282/pdf/CHRG-116hhrg38282.pdf

[93] Hearing titled, "The Boeing 737 MAX: Examining the Design, Development, and Marketing of the Aircraft," Committee on Transportation and Infrastructure, U.S. House of Representatives, 116th Congress, First Session, October 30, 2019, p. 20, accessed here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg38282/pdf/CHRG-116hhrg38282.pdf

[94] Dr. Mica Endsley, a Committee Chair at the Human Factors and Ergonomics Society and a former Chief Scientist of the U.S. Air Force testified before the Transportation and Infrastructure Committee in December 2019. She pointed out: "It is critical that the automation mode and status be clearly and saliently displayed. In this case a display showing that the MCAS was on and each time it engaged, as well as its effect on aircraft trim, would have provided key input to the pilots as to what the system was doing. If the MCAS is overridden by the pilot and turned off, this should be displayed as well to provide clear feedback to the pilots on its state." See: Dr. Mica R. Endsley, Prepared Testimony, "The Boeing 737 MAX: Examining the Federal Aviation Administration's Oversight of the Aircraft's Certification," Committee on Transportation and Infrastructure, U.S. House of Representatives, 116th Congress, First Session, December 11, 2019, accessed here: https://transportation.house.gov/committee-activity/hearings/the-boeing-737-max-examining-the-federal-aviation-administrations-oversight-of-the-aircrafts-certification

[95] Boeing ITRACS Item, "MCAS/Speed Trim," 37MAXFCI-PDR AI22, BATES Number TBC T&I 549172-549173. (On file with the Committee).

[96] Boeing internal email, "Subject: PRG – 37MAXFCI-PDR_AI22 – MCAS/Speed Trim," June 7, 2013, at p. 93, accessed here: https://transportation.house.gov/imo/media/doc/Compressed%20Updated%202020.01.09%20Boeing%20Production.pdf

Exhibit 12: House Committee concluded Boeing concealed critical information [4].

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accountable for knowingly delivering aircraft with non-functioning AOA Disagree alerts to their customer airlines and failing to inform MAX pilots or the FAA that an item that was supposed to be a standard feature in the cockpit was inoperable.

737 MAX Pilot Training – ***Boeing's economic incentives led the company to a significant lack of transparency with the FAA, its customers, and 737 MAX pilots regarding pilot training requirements and negatively compromised safety.***

- Boeing had tremendous financial incentive to ensure that no regulatory determination requiring pilot simulator training for the 737 MAX was made. Under a contract signed in December 2011 with Southwest Airlines, the U.S. launch customer for the 737 MAX, Boeing was financially obligated to have discounted the price of each MAX airplane it delivered to Southwest by at least $1 million if the FAA had required simulator training for pilots transitioning from the 737 NG to the 737 MAX.[125]

- Southwest had 200 firm orders for the MAX with the option to purchase an additional 191 MAX aircraft.[126] Thus, if Boeing failed to obtain Level B (non-simulator) training requirements or less from the FAA it would have owed Southwest between $200 to nearly $400 million.[127] This helped incentivize Boeing and its leadership to forestall any simulator training for 737 MAX pilots. This had the impact of evading and averting the inclusion of at least one technology that could have affected Boeing's directive to avoid simulator training.

- In November 2012, for instance, it took a Boeing test pilot more than 10 seconds to respond to uncommanded MCAS activation during a flight simulator test, a condition the pilot found to be "catastrophic[.]"[128] The FAA has provided guidance that pilots should be able to respond to this condition within four seconds.[129] This event should have focused Boeing's attention on the need for enhanced pilot training for MAX pilots. It didn't.

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[125] See: Letter from Southwest Airlines' Drew Richardson to Chair DeFazio and Subcommittee on Aviation Chair Rick Larsen, July 26, 2019, (On file with the Committee), and David Shepardson and Tracy Rucinski, "U.S. lawmakers question Boeing's $1 mln rebate clause for Southwest 737 MAX orders," *Reuters,* October 30, 2019, accessed here: https://www.reuters.com/article/us-boeing-airplane-southwest/u-s-lawmakers-question-boeings-1-mln-rebate-clause-for-southwest-737-max-orders-idUSKBN1X92D4

[126] "Southwest Airlines Reports Fourth Quarter And Record Annual Profit; 44th Consecutive Year Of Profitability," Southwest Airlines Company, January 26, 2017, accessed here: http://www.southwestairlinesinvestorrelations.com/tools/viewpdf.aspx?page={55E44CBF-22E3-41F5-84EF-B3EDAB030B07}

[127] In January 2017, Southwest had 200 firm 737 MAX orders with the option to purchase 191 additional MAX aircraft. In October 2019, one year after the Lion Air crash, Southwest had 246 firm MAX orders, 34 of its MAX aircraft were grounded and it had the option to purchase 115 additional MAX aircraft. See: "Southwest Airlines Reports Fourth Quarter And Record Annual Profit; 44th Consecutive Year Of Profitability," Southwest Airlines Company, January 26, 2017, accessed here: http://www.southwestairlinesinvestorrelations.com/tools/viewpdf.aspx?page={55E44CBF-22E3-41F5-84EF-B3EDAB030B07}; "Southwest Corporate Fact Sheet," Southwest Airlines Company, 2020, accessed here: https://www.swamedia.com/pages/corporate-fact-sheet#fleet and "Southwest Reports Record Third Quarter Net Income And Earnings Per Share," Southwest Airlines Company, October 24, 2019, accessed here: http://www.southwestairlinesinvestorrelations.com/news-and-events/news-releases/2019/10-24-2019-112936719

[128] Internal email from Boeing engineer to two Boeing test pilots, "Subject: MCAS Hazard Assessment," Sent: November 1, 2012, 2:40 PM, BATES Number TBC T&I 131226 – 131227 (On file with the Committee).

[129] See: JATR Report p.14 and FAA Advisory Circular 25.1329-1C, October 27, 2014, p. 78, accessed here: https://www.faa.gov/documentLibrary/media/Advisory_Circular/AC_25_1329-1C.pdf

Exhibit 13: Examples of Boeing's lack of transparency/concealment related to training needs [4].

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- From 2015 to 2018, the information regarding the fact that Boeing's own test pilot took more than 10 seconds to respond to uncommanded MCAS activation in a flight simulator leading to potentially "catastrophic" consequences was included in at least six separate internal Boeing Coordination Sheets on MCAS's requirements.[130] This indicates Boeing's keen awareness of the importance of this information.

- The Committee has found no evidence that Boeing shared this information with the FAA, its customers, or 737 MAX pilots and Boeing has confirmed to the Committee that it found no record showing it shared any of these MCAS Coordination Sheets with the FAA because they were not required to do so.

- At least four Boeing ARs were aware of these findings and never reported them to the FAA.

- One of Boeing's key goals for the 737 MAX program was that simulator-based training would not be required for pilots transitioning to the 737 MAX from the 737 NG.[131] That goal undermined appropriate pilot training requirements, hampered the development of safety features that conflicted with that goal and created management incentives to downplay the risks of technologies that jeopardized that goal.[132]

- Early in the 737 MAX program, for instance, Boeing recognized that the addition of MCAS to the pilot's flight controls system posed a risk to qualifying for Level B (non-simulator) training.[133]

- However, the chief project engineer on the MAX program told Committee staff that obtaining Level B (non-simulator) pilot training requirements from the FAA was a "design objective" of the MAX program.[134] That directive demanded that differences training for

[130] See: Boeing Coordination Sheet, "737MAX Flaps Up High Alpha Stabilizer Trim (MCAS) Requirements," No. Aero-B-BBA8-C12-0159, Model: 737-MAX (-7/8/9), Revision B, July 8, 2015, TBC T&I 191227 – TBC T&I 191232 at TBC T&I 191231 (On file with the Committee); Boeing Coordination Sheet, "737MAX Flaps Up High Alpha Stabilizer Trim (MCAS) Requirements," No. Aero-B-BBA8-C12-0159, Model: 737-MAX (-7/8/9), Revision C, October 19, 2015, TBC T&I 253262 - TBC T&I 253268 at TBC T&I 253267 (On file with the Committee); Boeing Coordination Sheet, "737MAX Flaps Up High Alpha Stabilizer Trim (MCAS) Requirements," No. Aero-B-BBA8-C12-0159, Model: 737-MAX (-7/8/9), Revision D, March 30, 2016, accessed at p. 164 here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg38282/pdf/CHRG-116hhrg38282.pdf; Boeing Coordination Sheet, "737MAX Flaps Up High Alpha Stabilizer Trim (MCAS) Requirements," No. Aero-B-BBA8-C12-0159, Model: 737-MAX (-7/8/9), Revision E, July 5, 2016, TBC T&I 129776 - TBC T&I 129782 at TBC T&I 129782 (On file with the Committee); Boeing Coordination Sheet, "737MAX Flaps Up High Alpha Stabilizer Trim (MCAS) Requirements," No. Aero-B-BBA8-C12-0159, Model: 737-MAX (-7/8/9), Revision F, December 20, 2017, TBC T&I 037449 - TBC T&I 037457 at TBC T&I 037457 (On file with the Committee); Boeing Coordination Sheet, "737MAX Flaps Up High Alpha Stabilizer Trim (MCAS) Requirements," No. Aero-B-BBA8-C12-0159, Model: 737-MAX (-7/8/9), Revision G, June, 11 2018, accessed at p. 174 here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg38282/pdf/CHRG-116hhrg38282.pdf

[131] Boeing internal email, "Subject: 737 MAX Firm Configuration Status/Help Needed," Sent: May 4, 2013 11:35 AM, BATES Number TBC-T&I 048706 – 048707, at pp. 128-129 accessed here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg38282/pdf/CHRG-116hhrg38282.pdf

[132] Ibid.

[133] Ibid.

[134] Committee staff interview of Michael Teal, former Vice President, Chief Project Engineer and Deputy Program Manager of the 737 MAX Program, Boeing Commercial Airplanes, May 11, 2020.

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Exhibit 14: Examples of Boeing's lack of transparency related to training needs [1].

Boeing's 737 Chief Technical Pilot strongly opposed such training, and in one case even successfully talked a carrier out of using such training for its pilots on the 737 MAX.[143]

- In December 2017, the Chief Technical Pilot referring to his efforts to talk airlines out of the need for simulator training wrote to a Boeing colleague: "I save this company a sick amount of $$$$."[144]

- Even after the fatal Lion Air crash, Boeing maintained that its "rationale" for removing references to MCAS from the 737 MAX training manual was still "valid,"[145] and Boeing asserted that the addition of MCAS on the 737 MAX did "not affect pilot knowledge, skills, abilities, or flight safety."[146]

- After the Lion Air crash, Boeing also recommended that FAA only require Level A training on MCAS.[147] This is the training level with the fewest obligations, and would only require pilots to review printed materials that described MCAS as part of their transition from the 737 NG to the 737 MAX.[148]

- On March 1, 2019, the FAA reminded Boeing that the original level of differences training proposed in 2016 by Boeing—**before** the Lion Air crash—was Level B.[149] The FAA informed Boeing that the software changes to MCAS "may not meet the definition of Level

[143] See: Boeing internal email, "Subject: RE: 737 MAX ATB/RTL FOTB" Sent: Monday, June 5, 2018, 8:01 PM (p. 14); Boeing Email to airline customer, "Subject: RE: MAX LEVEL B DIFFERENCES SOLUTION," Sent: Tuesday, June 6, 2017 11:01:40 AM (p. 34); Airline customer Email to Boeing, "Subject: RE: MAX LEVEL B DIFFERENCES SOLUTION," Sent: Wednesday, June 7, 2017, 12:12 AM (p. 32); and Boeing internal email, "Subject: FW: MAX LEVEL B DIFFERENCES SOLUTION," Sent: Wednesday, June 7, 2017, 10:01:41 AM (p. 32); accessed here (at page numbers indicated in parenthesis): https://transportation.house.gov/imo/media/doc/Compressed%20Updated%202020.01.09%20Boeing%20Production.pdf

[144] Boeing internal instant message, December 12, 2017, at p. 87, accessed here: https://transportation.house.gov/imo/media/doc/Compressed%20Updated%202020.01.09%20Boeing%20Production.pdf

[145] Boeing Letter to FAA's Seattle Aviation Evaluation Group (AEG), January 30, 2019—TBC-T&I 297017–297018, at pp. 134-135, accessed here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg38282/pdf/CHRG-116hhrg38282.pdf

[146] Ibid.

[147] Ibid. FAA has defined five training levels, in order of increasing requirements identified as A through E, that describe acceptable training and checking methods that are appropriate to the degree of difference between the base aircraft and the variations. See: FAA Flight Standards Information Management System, 8900.1 Contents, Volume 3 General Technical Administration, Chapter 19 Flightcrew Member Training and Qualification Programs, Section 9 Safety Assurance System: Differences Training—All Training Categories, accessed here: http://fsims.faa.gov/wdocs/8900.1/v03%20tech%20admin/chapter%2019/03_019_009.htm

[148] FAA Flight Standards Information Management System, 8900.1 Contents, Volume 3 General Technical Administration, Chapter 19 Flightcrew Member Training and Qualification Programs, Section 9 Safety Assurance System: Differences Training—All Training Categories, accessed here: http://fsims.faa.gov/wdocs/8900.1/v03%20tech%20admin/chapter%2019/03_019_009.htm

[149] FAA letter to Boeing 737 Chief Technical Pilot, "Subject: Boeing 737-8 Maneuver Characteristic Augmentation System (MCAS) Evaluation Letter of Proposal RA-19-0029 FAA Response Letter," March 1, 2019, BATES Number TBC-T&I 297019 – 297020, at pp. 136-137, accessed here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg38282/pdf/CHRG-116hhrg38282.pdf

Exhibit 15: Examples of Boeing's lack of transparency related to training needs [1].

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A differences" training and advised Boeing that the company's "evaluation is proceeding at risk."[150] Nine days later, Ethiopian Airlines flight 302 crashed.

Post-Accident Response - ***Both Boeing and the FAA gambled with the public's safety in the aftermath of the Lion Air crash, resulting in the death of 157 more individuals on Ethiopian Airlines flight 302, less than five months later.***

- After the Lion Air crash, Boeing and the FAA failed to take the actions needed to avert a second crash. In November 2018, days after the Lion Air crash, both Boeing and the FAA issued advisories for 737 MAX pilots that failed to even mention the existence of MCAS by name.[151] Only after receiving inquiries about MCAS from airlines did Boeing describe MCAS in a Multi Operator Message (MOM), on November 10, 2018, that went to Boeing's MAX customers but was not otherwise made public.[152]

- The FAA acknowledged to the Committee that it had drafted—and then deleted—reference to MCAS that had originally appeared in a draft of its Emergency Airworthiness Directive (AD).[153]

- There were multiple red flags and clear data points that should have informed the FAA's decision-making after the Lion Air crash. The FAA learned, for instance, that not only had Boeing failed to fix an inoperable AOA Disagree alert on more than 80 percent of the 737 MAX fleet, but that it had also decided not to inform the FAA or its customers about the non-functioning alert for more than 14 months – until **after** the Lion Air crash.[154]

- Moreover, in December 2018, the FAA received a briefing from Boeing in which the company acknowledged that prior to certification, Boeing had not evaluated the effects of a combination of failures leading to unintended MCAS activation in simulator tests nor their combined flight deck effects on pilots.[155] Boeing also acknowledged that it did not reevaluate

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[150] Ibid.
[151] Flight Crew Operations Manual Bulletin for the Boeing Company, Number TBC-19, 737-8/-9, Uncommanded Nose Down Stabilizer Trim Due To Erroneous Angle of Attack (AOA) During Manual Flight Only, November 6, 2018, accessed here at pp. 95-96: https://www.govinfo.gov/content/pkg/CHRG-116hhrg38282/pdf/CHRG-116hhrg38282.pdf and FAA Emergency Airworthiness Directive # 2018-23-51, November 7, 2018, accessed here: https://rgl.faa.gov/Regulatory_and_Guidance_Library/rgad.nsf/0/83ec7f95f3e5bfbd8625833e0070a070/$FILE/2018-23-51_Emergency.pdf
[152] The Boeing Company Multi Operator Message (MOM), Subject: Information – Multi-Modal Stall Warning and Pitch Augmentation Operation, MOM-MOM-18-0655-01B, November 10, 2018, p. 290, accessed here: https://aviation-is.better-than.tv/737%20MAX%202018%20-%20035%20-%20PK-LQP%20Final%20Report.pdf
[153] Questions from Hon. Peter A. DeFazio for Hon. Stephen M. Dickson, Administrator, Federal Aviation Administration, Hearing titled: "The Boeing 737 MAX: Examining the Federal Aviation Administration's Oversight of the Aircraft's Certification," Committee on Transportation and Infrastructure, U.S. House of Representatives, 116th Congress, First Session, December 11, 2019, accessed here at pp. 243-244: https://www.govinfo.gov/content/pkg/CHRG-116hhrg40697/pdf/CHRG-116hhrg40697.pdf
[154] Alan Levin, "Boeing Failure to Fix 737 MAX Warning Light May Draw FAA Penalty," *Bloomberg*, February 21, 2020, accessed here: https://www.bloomberg.com/news/articles/2020-02-21/boeing-failure-to-fix-737-max-cockpit-light-may-draw-faa-penalty and "Boeing Statement on AOA Disagree Alert," Press Release, The Boeing Company, accessed here: https://boeing.mediaroom.com/news-releases-statements?item=130431
[155] MCAS Development and Certification Overview—TBC-T&I 130073–130074; 130075–130117, at pp. 178-179, 180-201, at p. 185, accessed here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg38282/pdf/CHRG-116hhrg38282.pdf

Exhibit 16: Continued lack of transparency/concealment and materially false and misleading information following the tragic 2018 Lion Air crash [4].

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INVESTIGATIVE FINDINGS - Continued

- In 2012, at the start of the 737 MAX program, it took a Boeing test pilot more than 10 seconds to respond to uncommanded[517] MCAS activation in a flight simulator, which the pilot found to be "catastrophic[.]"[518] Boeing never shared this information with the FAA, its MAX customers, or MAX pilots.

New Larger Engines Resulted in Aerodynamic Instability in Critical Situations

In 2011, facing a competitive threat from Airbus's new, more fuel efficient, single-aisle A320 aircraft, Boeing believed it did not have time to create a new plane from scratch.[519] Instead, it opted to modify its existing 737 NG aircraft to make it more fuel efficient.[520] To help accomplish this, Boeing installed, larger, more fuel efficient engines on this new 737 derivative airplane model dubbed the 737 MAX aircraft.[521]

The existing engines on the 737 NG aircraft were located under the wings and already hung relatively low to the ground, a vestige of the 737's original 1967 design—a time when stairs were more commonly used by passengers to board planes than jetways, and ground crews more commonly hand-lifted luggage into cargo holds, as opposed to using motorized belt loaders.[522] As a result, there was not enough ground clearance to simply swap out the old engines and replace them with new, larger, more efficient ones.[523]

The engines on the 737 NG have a ground clearance of 17 inches.[524] By comparison, Boeing's 757 model aircraft has a minimum clearance of 29 inches and Boeing's 787 Dreamliner has a minimum clearance of 28 inches.[525] The 737 NG engine hangs so low that the otherwise circular casing around it, known as a nacelle, is flattened at the bottom – giving it a look that some pilots have dubbed the "hamster pouch."[526]

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[517] MCAS was designed to activate automatically without any pilot command. Use of the term "uncommanded" in connection with MCAS activation here is for consistency with Boeing's own Functional Hazard Assessments which measured, "Uncommanded MCAS function operation to pilot reaction[,]" and observed that a "slow reaction time scenario (> 10 seconds) found the failure to be catastrophic due to the inability to arrest the airplane overspeed." See Hearing titled, "The Boeing 737 MAX: Examining the Design, Development, and Marketing of the Aircraft," Committee on Transportation and Infrastructure, U.S. House of Representatives, 116th Congress, First Session, October 30, 2019, pp. 163-164 and 173-174, accessed here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg38282/pdf/CHRG-116hhrg38282.pdf

[518] Boeing internal email from Boeing engineer to two Boeing test pilots, "Subject: MCAS Hazard Assessment," November 1, 2012, BATES Number TBC T&I 131226-131227. (On file with the Committee).

[519] David Gelles, Natalie Kitroeff, Jack Nicas and Rebecca Ruiz, "Boeing Was 'Go, Go, Go' to Beat Airbus With the 737 Max," *New York Times*, March 23, 2019, accessed here: https://www.nytimes.com/2019/03/23/business/boeing-737-max-crash.html

[520] Ibid.

[521] Ibid.

[522] Ralph Vartabedian, "How a 50-year-old design came back to haunt Boeing with its troubled 737 Max jet," *Los Angeles Times*, March 15, 2019, accessed here: https://www.latimes.com/local/california/la-fi-boeing-max-design-20190315-story.html

[523] Ibid.

[524] Ibid.

[525] Ibid.

[526] Ibid.

Exhibit 17: Boeing knew, as of 2012, and originally concealed from the FAA that pilot reaction time may be slower by a factor of 2 to 3 than an assumed maximum response time of 4 seconds [4].

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The Boeing engineer asked a series of questions in the email that became extremely relevant after the Lion Air and Ethiopian Airlines crashes. As in several other cases, the Committee found Boeing engineers asked the right questions concerning key details, but they were inadequately resolved or dismissed by some of their colleagues. If these crucial questions had been more thoroughly addressed at the time, they could have helped, in some cases potentially dramatically, to improve the safety of the 737 MAX.

Specifically, the Boeing employee asked his colleagues:

> Do you think that with pilot training/knowledge of the [MCAS] system there will be a sufficiently quick response to the stab runaway during the windup turn/recovery and that it is appropriate to deem it hazardous and have the MCAS system designed to meet this? Or should we step up to catastrophic with the assumption that not all pilots will recognize it quickly enough?[675]

That was a revelatory observation. On each of the doomed MAX flights a cacophony of alerts and warnings were erupting on the flight deck in the minutes prior to the crashes. A combination of issues led to the Lion Air and Ethiopian Airlines crashes, but confusion on the flight deck played a key factor in both accidents.[676]

Despite the fact that Boeing knew that the consequences could be "catastrophic" if a pilot did not react quickly enough to uncommanded MCAS activation, and the fact that Boeing cited this fact repeatedly over the years in their internal coordination sheets on MCAS, based on their own internal test data, no one at Boeing apparently informed the FAA about this critical data.[677] Between 2015 and 2018 Boeing issued six separate coordination sheets on MCAS that referenced the "catastrophic" consequences of a greater than 10-second pilot response time.[678] At least four Boeing

[675] Ibid.
[676] "Safety Recommendation Report: Assumptions Used in the Safety Assessment Process and the Effects of Multiple Alerts and Indications on Pilot Performance," National Transportation Safety Board (NTSB), September 19, 2019, p. 8, accessed here: https://www.ntsb.gov/investigations/AccidentReports/Reports/ASR1901.pdf
[677] Email from Boeing attorney to Committee staff, February 10, 2020, 10:42 PM (On file with the Committee).
[678] See: Boeing Coordination Sheet, "737MAX Flaps Up High Alpha Stabilizer Trim (MCAS) Requirements," No. Aero-B-BBA8-C12-0159, Model: 737-MAX (-7/8/9), Revision B, July 8, 2015, TBC T&I 191227 - TBC T&I 191232 at TBC T&I 191231 (On file with the Committee); Boeing Coordination Sheet, "737MAX Flaps Up High Alpha Stabilizer Trim (MCAS) Requirements," No. Aero-B-BBA8-C12-0159, Model: 737-MAX (-7/8/9), Revision C, October 19, 2015, TBC

Exhibit 18: Boeing engineers questioning pilot response time was not disclosed to FAA [4].

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ARs, reviewed, prepared, approved and/or were copied on these coordination sheets.[679] The Committee has been unable to find any indication that any of these ARs informed the FAA about this critical test data. Moreover, Boeing has informed the Committee that it has been unable to locate any record showing that any of these coordination sheets were shared with the FAA.[680]

The language throughout the years in the Boeing coordination sheets remained virtually unchanged regarding the consequences of the 10-second pilot reaction time. It said:

> Stabilizer runaways to pilot reaction (item D) were performed. These failures were arrested by use of the aisle stand cutout switch when the pilot recognized and reacted to the runaway. Assessments were done during WUTs only i.e. within the operational flight envelope, but not assessed by mistrim trim dive recoveries (normal operating envelope). With pilot training to recognize the runaway and use of teamwork, the failure was found Hazardous, which is the same as the item C finding. A typical reaction time was observed to be approximately 4 seconds. A slow reaction time scenario (>10 seconds) found the failure to be catastrophic due to the inability to arrest the airplane overspeed.[681]

Boeing MCAS Coordination Sheets 2015-2018

"A SLOW REACTION TIME SCENARIO (>10 SECONDS) FOUND THE FAILURE TO BE CATASTROPHIC DUE TO THE INABILITY TO ARREST THE AIRPLANE OVERSPEED."

Boeing produced two of these coordination sheets in 2015, two in 2016, and one in 2017. It is notable that Boeing also produced an updated coordination sheet on June 11, 2018, more than one year after the 737 MAX had been certified by the FAA and was already flying in commercial service, and the assessment of a pilot taking more than 10-seconds to react to uncommanded MCAS activation remained unchanged.[682] Yet the FAA, as well as MAX pilots and airlines that purchased the 737 MAX aircraft were unaware of Boeing's findings regarding the catastrophic consequences of a greater than 10-second reaction time to uncommanded

T&I 253262 - TBC T&I 253268 at TBC T&I 253267 (On file with the Committee); and Boeing Coordination Sheet, "737MAX Flaps Up High Alpha Stabilizer Trim (MCAS) Requirements," No. Aero-B-BBA8-C12-0159, Model: 737-MAX (-7/8/9), Revision D, March 30, 2016, accessed at p. 164 here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg38282/pdf/CHRG-116hhrg38282.pdf; Boeing Coordination Sheet, "737MAX Flaps Up High Alpha Stabilizer Trim (MCAS) Requirements," No. Aero-B-BBA8-C12-0159, Model: 737-MAX (-7/8/9), Revision E, July 5, 2016, TBC T&I 129776 - TBC T&I 129782 at TBC T&I 129782 (On file with the Committee); Boeing Coordination Sheet, "737MAX Flaps Up High Alpha Stabilizer Trim (MCAS) Requirements," No. Aero-B-BBA8-C12-0159, Model: 737-MAX (-7/8/9), Revision F, December 20, 2017, TBC T&I 037449 - TBC T&I 037457 at TBC T&I 037457 (On file with the Committee); Boeing Coordination Sheet, "737MAX Flaps Up High Alpha Stabilizer Trim (MCAS) Requirements," No. Aero-B-BBA8-C12-0159, Model: 737-MAX (-7/8/9), Revision G, June, 11 2018, accessed at p. 174 here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg38282/pdf/CHRG-116hhrg38282.pdf

[679] Ibid.

[680] Email from Boeing attorney to Committee staff, February 10, 2020, 10:42 PM. (On file with the Committee).

[681] Boeing Coordination Sheet, "737MAX Flaps Up High Alpha Stabilizer Trim (MCAS) Requirements," October 19, 2015, TBC-T&I 253262 - TBC-T&I 253268 at TBC-T&I 253262 at TBC-T&I 253267. (On file with the Committee).

[682] Boeing Coordination Sheet, "737MAX Flaps Up High Alpha Stabilizer Trim (MCAS) Requirements," No. Aero-B-BBA8-C12-0159, Model: 737-MAX (-7/8/9), Revision G, June, 11 2018, accessed at p. 174 here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg38282/pdf/CHRG-116hhrg38282.pdf

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Exhibit 19: Boeing concealed their data related to slow reaction times to customers or FAA [4].

-FINAL COMMITTEE REPORT: BOEING 737 MAX-
11. Final Observations

Instead of acknowledging in its reply that Boeing learned post crashes that its design was flawed, or that it had made mistakes, Boeing blamed industry-wide assumptions regarding pilot response times:

> In designing MCAS, Boeing relied on well-accepted, industry-wide assumptions in evaluating how pilots would react to the uncommanded activation of MCAS for any reason, including erroneous AOA. Those assumptions proved not to be accurate in these accidents. Accordingly, we now know that there is a greater risk from unintended activation of MCAS due to erroneous AOA data than we originally thought. Our system redesign addresses this issue.[1346]

Except as the Committee's investigation has shown, Boeing **did**, in fact, have information that those industry-wide assumptions were wrong. Boeing knew this because it had internal test data it had acquired as early as November 2012 that its own test pilot took more than 10 seconds to respond to uncommanded MCAS activation during a test scenario in a flight simulator, a condition the pilot found to be "catastrophic[.]"[1347] Boeing clearly realized the significance of a delayed response to MCAS activation because it described this "catastrophic" test result in six separate Coordination Sheets about MCAS that were completed from 2015 to 2018.[1348] What is less clear is why Boeing never shared this important data with the FAA, its customers, or 737 MAX pilots.

Boeing's reluctance to admit mistakes is also evident in its response to another question for the record from Rep. Sharice Davids in which she asked if Boeing had taken any disciplinary action against employees who were aware that the AOA Disagree alert was not functioning on the majority of MAX airplanes prior to the Lion Air crash and failed to take appropriate steps to inform the FAA or Boeing's customers.[1349] In its reply, Boeing said the priority was returning the 737 MAX to service:

[1346] Ibid.
[1347] Ibid.
[1348] Boeing Coordination Sheet, "737MAX Flaps Up High Alpha Stabilizer Trim (MCAS) Requirements," No. Aero-B-BBA8-C12-0159, Model: 737-MAX (-7/8/9), Revision B, July 8, 2015, TBC T&I 191227 - TBC T&I 191232 at TBC T&I 191231 (On file with Committee); Boeing Coordination Sheet, "737MAX Flaps Up High Alpha Stabilizer Trim (MCAS) Requirements," No. Aero-B-BBA8-C12-0159, Model: 737-MAX (-7/8/9), Revision C, October 19, 2015, TBC T&I 253262 - TBC T&I 253268 at TBC T&I 253267 (On file with Committee); Boeing Coordination Sheet, "737MAX Flaps Up High Alpha Stabilizer Trim (MCAS) Requirements," No. Aero-B-BBA8-C12-0159, Model: 737-MAX (-7/8/9), Revision D, March 30, 2016, accessed at p. 164 here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg38282/pdf/CHRG-116hhrg38282.pdf; Boeing Coordination Sheet, "737MAX Flaps Up High Alpha Stabilizer Trim (MCAS) Requirements," No. Aero-B-BBA8-C12-0159, Model: 737-MAX (-7/8/9), Revision E, July 5, 2016, TBC T&I 129776 - TBC T&I 129782 at TBC T&I 129782 (On file with Committee); Boeing Coordination Sheet, "737MAX Flaps Up High Alpha Stabilizer Trim (MCAS) Requirements," No. Aero-B-BBA8-C12-0159, Model: 737-MAX (-7/8/9), Revision F, December 20, 2017, TBC T&I 037449 - TBC T&I 037457 at TBC T&I 037457 (On file with Committee); Boeing Coordination Sheet, "737MAX Flaps Up High Alpha Stabilizer Trim (MCAS) Requirements," No. Aero-B-BBA8-C12-0159, Model: 737-MAX (-7/8/9), Revision G, June, 11 2018, accessed at p. 174 here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg38282/pdf/CHRG-116hhrg38282.pdf
[1349] Hearing titled, "The Boeing 737 MAX: Examining the Design, Development, and Marketing of the Aircraft," Committee on Transportation & Infrastructure, U.S. House of Representatives, 116th Congress, First Session, October 30, 2019, p. 281, accessed here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg38282/pdf/CHRG-116hhrg38282.pdf

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Exhibit 20: Boeing indirectly acknowledges delay of risk-reduction as a result of concealing information [4].

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Flight Crew Operations Manual Bulletin for The Boeing Company, No. TBC–19, Issued Nov. 6, 2018, Submitted for the Record by Hon. Plaskett

BOEING

Flight Crew Operations Manual Bulletin
for
The Boeing Company

The Boeing Company
Seattle, Washington 98124-2207

737

Number: TBC-19
IssueDate: November 6, 2018

Airplane Effectivity: 737-8 / -9

Subject: Uncommanded Nose Down Stabilizer Trim Due to Erroneous Angle of Attack (AOA) During Manual Flight Only

Reason: To Emphasize the Procedures Provided in the Runaway Stabilizer Non-Normal Checklist (NNC).

Information in this bulletin is recommended by The Boeing Company, but may not be FAA approved at the time of writing. In the event of conflict with the FAA approved Airplane Flight Manual (AFM), the AFM shall supersede. The Boeing Company regards the information or procedures described herein as having a direct or indirect bearing on the safe operation of this model airplane.

THE FOLLOWING PROCEDURE AND/OR INFORMATION IS EFFECTIVE UPON RECEIPT

Background Information

The Indonesian National Transportation Safety Committee has indicated that Lion Air flight 610 experienced erroneous AOA data. Boeing would like to call attention to an AOA failure condition that can occur **during manual flight only.** This bulletin directs flight crews to existing procedures to address this condition.

In the event of erroneous AOA data, the pitch trim system can trim the stabilizer nose down in increments lasting up to 10 seconds. The nose down stabilizer trim movement can be stopped and reversed with the use of the electric stabilizer trim switches but may restart 5 seconds after the electric stabilizer trim switches are released. Repetitive cycles of uncommanded nose down stabilizer continue to occur unless the stabilizer trim system is deactivated through use of both STAB TRIM CUTOUT switches in accordance with the existing procedures in the Runaway Stabilizer NNC. It is possible for the stabilizer to reach the nose down limit unless the system inputs are counteracted completely by pilot trim inputs and both STAB TRIM CUTOUT switches are moved to CUTOUT.

Exhibit 21: Release of additional information, but not full disclosure of facts associated with MCAS following the Lion Air incident in November of 2018 (Source: House Report, page 95, [5]).

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Flight Crew Operations Manual Bulletin No. TBC-19 , Dated November 6, 2018 (continued)

Additionally, pilots are reminded that an erroneous AOA can cause some or all of the following indications and effects:

- Continuous or intermittent stick shaker on the affected side only.
- Minimum speed bar (red and black) on the affected side only.
- Increasing nose down control forces.
- Inability to engage autopilot.
- Automatic disengagement of autopilot.
- IAS DISAGREE alert.
- ALT DISAGREE alert.
- AOA DISAGREE alert (if the AOA indicator option is installed)
- FEEL DIFF PRESS light.

Operating Instructions

In the event an uncommanded nose down stabilizer trim is experienced on the 737-8 /-9, in conjunction with one or more of the above indications or effects, do the Runaway Stabilizer NNC ensuring that the STAB TRIM CUTOUT switches are set to CUTOUT and stay in the CUTOUT position for the remainder of the flight.

Note: Initially, higher control forces may be needed to overcome any stabilizer nose down trim already applied. Electric stabilizer trim can be used to neutralize control column pitch forces before moving the STAB TRIM CUTOUT switches to CUTOUT. Manual stabilizer trim can be used after the STAB TRIM CUTOUT switches are moved to CUTOUT.

Administrative Information

Insert this bulletin behind the Bulletin Record page in Volume 1 of your Flight Crew Operations Manual (FCOM). Amend the FCOM Bulletin Record page to show bulletin TBC-19 "In Effect" (IE).

This Bulletin remains in effect until Boeing provides additional information on system updates that may allow this Bulletin to be canceled.

Please send all correspondence regarding Flight Crew Operations Manual Bulletin status, to the 737 Manager, Flight Technical Data, through the Service Requests Application (SR App) on the MyBoeingFleet home page.

Exhibit 22: 2nd page of the November 2018 notice put out by Boeing November of 2018 (Source: House Report, page 96, [5]).

-FINAL COMMITTEE REPORT: BOEING 737 MAX-
7. Boeing 737 MAX Pilot Training

INVESTIGATIVE FINDINGS - Continued

- The 737 Chief Technical Pilot also boasted that his efforts to talk airlines out of simulator training saved Boeing "a sick amount of $$$$."[829]
- In January 2020, Boeing made a stunning reversal of its previous goal to prevent pilot simulator training and recommended that simulator training be required for all MAX pilots once the plane is ungrounded and returns to service.[830]

Faulty Assumptions

Development of the MAX was marred by multiple faulty assumptions and financial pressures from the very start. The assumption that pilots transitioning from the 737 NG to the 737 MAX would only need a limited amount of differences training and no simulator training diminished safety, minimized the value of pilot training, and inhibited technical design improvements. The increased costs to Boeing's customer airlines in providing simulator training for MAX pilots and the increased costs to Boeing of adding new design features that could lead to heightened pilot training requirements drove critical decisions on the 737 MAX program.

Boeing has tacitly conceded the failure of its previous pilot training assumptions by announcing in January 2020 that it will now recommend simulator training for MAX pilots.[831] On the technical side, Boeing's faulty assumptions undermined safety and led, for example, to a lack of redundant features on MCAS.[832] Financial considerations also contributed to Boeing's decisions not to include certain safety features on the aircraft, such as a synthetic airspeed indicator, that would have increased costs and may have created potential simulator training requirements.[833]

Financial pressures to limit pilot training requirements permeated critical design and development decisions within the MAX program. Boeing assumed that despite new technologies being added to the MAX aircraft, particularly the inclusion of MCAS, pilots would not need to be specifically trained to respond to potential MCAS failures, for instance, or even to be aware MCAS existed.[834] More than any other program objective, ensuring that the FAA's pilot training requirements for the MAX did not include simulator training had an incredibly significant cascading effect on the 737 MAX program that undermined the safety of the flying public.

[829] Boeing internal instant message, December 12, 2017, BATES Number TBC-T&I549015 – TBC-T&I549016. (On file with the Committee).
[830] "Boeing Statement on 737 MAX Simulator Training," Press Release, The Boeing Company, January 7, 2020, accessed here: https://boeing.mediaroom.com/news-releases-statements?item=130596
[831] Ibid.
[832] Boeing employee email, "RE: MCAS Stab Rapid Reversal on PSIM Model," Sent: December 17, 2015,10:44:54 AM, BATES Number TBC-T&I 010584 - TBC-T&I 010586 at TBC-T&I 010584, accessed at p. 121 here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg38282/pdf/CHRG-116hhrg38282.pdf
[833] Boeing internal emails, "Subject: Synthetic Airspeed," February 26, 2013, at p. 1 accessed here: https://transportation.house.gov/imo/media/doc/Compressed%20Updated%202020.01.09%20Boeing%20Production.pdf
[834] Email from 737 Chief Technical Pilot to FAA, "Subject: MCAS lives in both FCCs," Sent: Wednesday, March 30, 2016, 11:16:45.

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Exhibit 23: Boeing recommends simulator training for all MAX pilots [4].

NOTICE

U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION

National Policy

N 8900.569

Effective Date: 11/18/20

Cancellation Date: 11/18/21

SUBJ: Boeing 737-8 and 737-9 Airplanes: Pilot Training

1. Purpose of This Notice. This notice provides policy, information, and direction regarding changes to Boeing 737-8 and 737-9 pilot training identified in the Federal Aviation Administration Flight Standardization Board (FSB) report The Boeing Company 737 Revision 17. Additional pilot training is required because The Boeing Company, Inc. has developed design changes and Airplane Flight Manual (AFM) revisions for Boeing 737-8 and 737-9 airplanes. The FAA mandated these design changes and AFM revisions in Airworthiness Directive (AD) 2020-24-02.

2. Audience.

a. Primary Audience. The primary audience for this notice is:

(1) Air Carrier and General Aviation Safety Assurance Principal Operations Inspectors (POI) and Aircrew Program Managers (APM) who are responsible for the oversight of Boeing 737-8 and 737-9 airplane operations for Title 14 of the Code of Federal Regulations (14 CFR) part 91 operators, part 121 air carriers, and part 125 operators; and

(2) Training Center Program Managers (TCPM) who are responsible for the oversight of part 142 training centers that operate Boeing 737-8 and 737-9 training programs.

b. Secondary Audience. The secondary audience includes other aviation safety inspectors (ASI) and other Flight Standards (FS) personnel.

3. Where You Can Find This Notice. You can find this notice on the MyFAA employee website at https://employees.faa.gov/tools_resources/orders_notices. Inspectors can access this notice through the Flight Standards Information Management System (FSIMS) at https://fsims.avs.faa.gov. Operators and other persons can find this notice on the FAA's website at https://fsims.faa.gov and https://www.faa.gov/regulations_policies/orders_notices.

4. Applicability. This notice applies to the Boeing 737-8 and 737-9 models of the Type Certificate Data Sheet (TCDS) A16WE. This notice will refer to these models collectively as the 737 MAX. This notice does not apply to the other models currently on the TCDS A16WE.

5. Background.

a. Accidents.

(1) On October 29, 2018, a Boeing 737-8 airplane operated by Lion Air (Lion Air Flight 610) was involved in an accident after takeoff from Soekarno-Hatta International Airport in Jakarta, Indonesia, resulting in 189 fatalities. Investigation of the accident has been completed by the Indonesian Komite Nasional Keselamatan Transportasi (KNKT) with assistance from the National Transportation Safety Board (NTSB) and the FAA of the United States, the manufacturer, and the operator. Reports from the accident investigation indicate that the airplane's flight control system generated repeated airplane nose-down horizontal stabilizer trim commands, contributing to

Exhibit 24: Requirement of Full Flight Simulation (FSS) per FAA Notice dated November 18, 2020 (Source: https://fsims.faa.gov/wdocs/notices/n8900_569.htm).

Summary of the FAA's Review of the Boeing 737 MAX

Identified Issue	FAA Determination of Issues That Must Be Addressed	Corrective Action*
Safety Item #3: MCAS TRIM AUTHORITY: All MCAS commands were incremental commands, which moved the horizontal stabilizer a fixed amount, regardless of the current position of the stabilizer. Therefore, multiple MCAS commands resulted in a significant horizontal stabilizer mistrim condition, which the flightcrew could not counter using only elevator control.	Ensure that if MCAS is erroneously activated, the MCAS system preserves the flightcrew's ability, using basic piloting techniques, to control the airplane after the activation.	Boeing changed flight control laws to include a limit for MCAS commands. The MCAS will stop commanding stabilizer movement at a point that preserves enough elevator movement for sufficient pilot control of aircraft pitch attitude for current operating conditions.
Safety Item #4: FLIGHTCREW RECOGNITION AND RESPONSE: FDR data from both accidents show that the flightcrews were unable to effectively manage the stabilizer movement and multiple flight deck effects that resulted from the single AOA sensor failure.	Ensure that after any foreseeable failure of the stabilizer system, safe flight is not dependent on the timeliness of the flightcrew performing a non-normal procedure.	In addition to the software changes noted in Safety Items #1, #2 and #3, Boeing revised or added eight non-normal flightcrew procedures to the Airplane Flight Manual and proposed additional training. The flightcrew procedures and the revised pilot training provide the pilot additional information to recognize and respond to erroneous stabilizer movement and the effects of potential AOA sensor failures.
Safety item #5: AOA DISAGREE: The AOA DISAGREE alert message on the Primary Flight Display is not functional unless the AOA indicator option was chosen by the airline. This alert message is intended to be standard on all 737 MAX airplanes.	Ensure 737 MAX Display System (MDS) software will alert the flightcrew with the AOA DISAGREE message if there is disagreement between the Left and Right AOA Sensors.	Boeing has revised the AOA DISAGREE alert message implementation to achieve the original design intent to be standard on all 737 MAX aircraft.
Safety Item #6: OTHER POSSIBLE FCC STABILIZER RUNAWAY FAILURES: A comprehensive review of the integrated System Safety Analysis (SSA) of MCAS by Boeing and the FAA identified an extremely remote FCC failure condition that required timely pilot intervention to ensure continued safe flight and landing.	Ensure that after any foreseeable failure of the stabilizer system, continued safe flight and landing is not dependent on the timeliness of the flightcrew performing a non-normal procedure.	Boeing implemented a cross FCC Trim Monitor, which can effectively detect and shut down erroneous stabilizer commands from the FCCs. This makes continued safe flight and landing for this type of failure not dependent on pilot reaction time.

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Exhibit 25: Safety Item #4 in FAA RTS report identifying corrective action of enhanced procedures and training [6].

protection against erroneous trim commands caused by possible — but unlikely — failures, such as a fault within a single integrated circuit in the FCC.

The software update to both primary flight displays (MAX Display System) includes improved AOA DISAGREE annunciation logic, which addresses Safety Item #5: AOA DISAGREE alert message. The AOA DISAGREE annunciation is now always enabled, regardless of the AOA gauge option. An additional improvement locks the AOA DISAGREE annunciation when the aircraft is below 400 feet in altitude.

To reflect the various updates, Boeing proposed eight new or changed procedures in the Airplane Flight Manual (AFM): SPEED TRIM FAIL, Airspeed Unreliable, AOA DISAGREE, ALTITUDE (ALT) DISAGREE, Runaway Stabilizer, Indicated Airspeed (IAS) DISAGREE, Stabilizer Trim Inoperative, and STAB OUT OF TRIM. These changes, along with certain changes to training (see below) address Safety Item #4: FLIGHTCREW RECOGNITION AND RESPONSE.

As a result of the design work to change the MCAS behavior and the subsequent review of the Integrated Speed Trim System Safety Analysis, the FAA required an additional evaluation of the related aircraft systems for all flight phases and system modes. The FAA evaluated Boeing's determination of a non-compliance with FAA wire separation requirements. As a result, Boeing developed changes to the system, which include physical separation of existing wires and/or routing of new wires in multiple areas of the Main Electric Trim and Auto Trim system.

Training Enhancements

The 737 MAX Joint Operations Evaluation Board (JOEB) concluded evaluation activities at London's Gatwick Airport on September 22, 2020. The JOEB included civil aviation authorities and airline flightcrews from the United States, Canada, Brazil and the European Union. The civil aviation authorities and industry pilots selected for participation completed all scheduled tasks as planned. The JOEB determined that all design changes applicable to the 737 MAX are operationally suitable. The Board's evaluations also included assessments of Boeing's proposed differences training and return to service training. The JOEB, through evaluations of multiple crews from a globally diverse pilot group, determined that the proposed training by the applicant was acceptable. The FAA posted the 737 Flight Standardization Board (FSB) report, revision 17, for public comment on October 6, 2020. The comment period closed on November 2, 2020.After considering the comments received, the FAA published the final version of the 737 FSB report, revision 17, on November 18, 2020. This revision adds training requirements for the MCAS, Autopilot Flight Director System (AFDS) enhancements, and additional Special Emphasis Training. The FAA added Appendix 7 to delineate 737 MAX ground and flight training necessary to operate the 737 MAX modified with the new FCC software. You can view the final report on this page.

Exhibit 26: Description of training enhancements based on JOEB evaluations [6].

Additionally, the following conditions are prerequisites to resuming operations in the U.S.:

- For previously delivered 737 MAX airplanes, owner/operators must incorporate all FAA-mandated design changes and maintenance actions.
- For any future delivered 737 MAX airplanes, Boeing is required to incorporate the same mandatory actions.

All US air-carrier pilots must complete the 737 MAX special training described in the 737 FSB report before serving in a 737 MAX airplane.

The FAA will issue a CANIC for the 737 MAX that provides information to the global aviation community on a comprehensive set of actions that must be taken by owner/operators to ensure a safe return to service. The FAA will issue the CANIC before it issues an AD containing mandatory continued airworthiness information (MCAI). As other CAAs consider returning the 737 MAX to service in their jurisdictions, the FAA strongly recommends:

- CAAs with 737 MAX aircraft on their respective registries should mandate the pilot training identified in the 737 MAX FSB report as a minimum starting point.
- Each State of Registry is responsible for the continued airworthiness and continued operational safety (COS) of aircraft on its registry. Accordingly, all States of Registry should adopt the final FAA AD and mandate the same changes in their own systems.

Conclusion

Through a thorough, transparent, and inclusive process, the FAA has determined that Boeing's proposed changes to the 737 MAX design, flightcrew procedures and maintenance procedures effectively mitigate the airplane-related safety issues that contributed to the Flight 610 and Flight 302 accidents. The FAA further determined that the proposed design change also address safety concerns beyond those that the accident investigations identified. This report does not address other safety issues that might have contributed to the accidents but are not related to airplane design. This includes the airline maintenance practices, the aircraft operators' compliance posture, and pilot training effectiveness. The FAA believes recommendations related to these other potential contributing factors should be addressed by the appropriate organizations.

Furthermore, the FAA and international aviation authorities evaluated Boeing's proposed flightcrew training through the FAA's Flight Standardization Board process. The FAA issued a Boeing 737 Flight Standardization Board Report documenting the results of the operational evaluation.

Exhibit 27: FAA concluded that the design and procedures updates mitigated the safety issues that contributed to the two crashes [6].

Summary of the FAA's Review of the Boeing 737 MAX

Recommendation Number	Recommendation	FAA Comment
A-19-013	Develop robust tools and methods, with the input of industry and human factors experts, for use in validating assumptions about pilot recognition and response to safety-significant failure conditions as part of the design certification process	Please refer to FAA Comment on recommendation A-19-016.
A-19-014	Once the tools and methods have been developed as recommended in Recommendation A-19-13, revise existing Federal Aviation Administration (FAA) regulations and guidance to incorporate their use and documentation as part of the design certification process, including re-examining the validity of pilot recognition and response assumptions permitted in existing FAA guidance.	Please refer to FAA Comment on recommendation A-19-016.
A-19-015	Develop design standards, with the input of industry and human factors experts, for aircraft system diagnostic tools that improve the prioritization and clarity of failure indications (direct and indirect) presented to pilots to improve the timeliness and effectiveness of their response	Please refer to FAA Comment on recommendation A-19-016.
A-19-016	Once the design standards have been developed as recommended in Recommendation A-19-15, require implementation of system diagnostic tools on transport-category aircraft to improve the timeliness and effectiveness of pilots' response when multiple flight deck alerts and indications are present	Safety recommendations A-19-013 through A-19-016 apply to developing new tools and methodologies for validating assumptions about pilot recognition and response to safety-significant failure conditions, with associated updates to regulations and policy as necessary. The FAA will consider all similar recommendations in formulating an overarching plan for research and possible updates to the agency's regulations, policy and guidance.

12.2 Joint Authorities Technical Review (JATR) Submittal

12.2.1 Description of Activity

The FAA Associate Administrator for Aviation Safety established the JATR to review the type certification of the flight control system on the 737 MAX. The JATR was chaired by Christopher Hart, an independent aviation safety professional and former Chairman of the NTSB. The remainder of the JATR team was comprised of 28 members from the FAA, NASA, and nine CAAs representing Australia, Brazil, Canada, China, the European Union, Indonesia, Japan, Singapore and the United Arab Emirates.

The FAA chartered the JATR to review the work conducted during the 737 MAX certification program to assess whether compliance was shown with the required

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Exhibit 28: Recommendation A-19-013 by the NTSB directly addresses the need to validate assumptions [6].

applicable airworthiness standards related to the flight control system and its interfaces, and to recommend improvements to the certification process if warranted. Of particular concern to the FAA in chartering the JATR was the function, evaluation and certification of the MCAS function on the 737 MAX. The JATR team also focused on flightcrew training and operational suitability of the design. The JATR team considered whether the appropriate regulations and policies were applied, as well as how applicable regulations and policy material could be improved to enhance safety.

12.2.2 Recommendations

Recommendation Number	Recommendation	Analysis for impact to 737 MAX RTS
1	Based on the JATR team's observations and findings related to the application of the Changed Product Rules to the certification of the flight control system of the 737 MAX, JATR team members recommend that the FAA work with other civil aviation authorities to revise the harmonized approach to the certification of changed products. Changed Product Rules (e.g., 14 CFR §§ 21.19 and 21.101) and associated guidance (e.g., AC 21.101-1B and FAA Orders 8110.4C and 8110.48A) should be revised to require a top-down approach, whereby every change is evaluated from an integrated whole-aircraft system perspective. These revisions should include criteria for determining when core attributes of an existing transport category aircraft design make it incapable of supporting the safety advancements introduced by the latest regulations and should drive a design change or a need for a new type certificate. The aircraft system includes the aircraft itself with all its subsystems, the flightcrew, and the maintenance crew. These Changed Product Rule revisions should take into consideration the following key principles: ▪ A comprehensive integrated system-level analysis recognizing that in this complex interactive system, every change could interact with other parts of the system. ▪ The assessment of proposed design changes on existing systems at the aircraft level includes using DA principles, system safety principles, and validation and verification techniques. The level of assessment should be proportional to the impact of the change at the aircraft level. ▪ The consideration of training and qualification of flight and maintenance personnel, as well as detailed explicit procedures for the safe operation of the aircraft.	This recommendation is for future certification policy changes and will require research and coordination with other CAAs. In relation to the FAA's approval of Boeing's 737 MAX current design changes, the agency's analysis included extensive evaluation of the integrated System Safety Analyses, including interaction between systems, a thorough review of design assurance processes, and a detailed examination and testing for appropriate training requirements.

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Exhibit 29: JATR recommendations of additional training [6].

APPENDIX 7. BOEING 737 MAX SPECIAL TRAINING FOR FLIGHTCREWS

The purpose of this appendix is to describe ground and flight training requirements associated with pilot qualification on the 737 MAX. The MDR Table makes reference to this appendix with the use of an asterisk (shown as E*).

No pilot may operate the 737 MAX unless the ground and flight training documented in this appendix has been completed. References to "pilots" in this section include both PICs and SICs unless otherwise specified. These Special Training segments can be standalone or embedded into another training curriculum. Some tasks outlined in this appendix are purposely omitted from Section 9.2, Special Emphasis Areas. The required training is as follows:

1. GROUND TRAINING

1.1 Training on the following NNCs:

- Runaway Stabilizer.
- SPEED TRIM FAIL.
- STABILIZER OUT OF TRIM.
- Stabilizer Trim Inoperative.
- Airspeed Unreliable.
- ALT DISAGREE.
- AOA DISAGREE.

1.2 Training in this section emphasizes the design differences associated with FCC software version P12.1.2 for the 737 MAX. This training also emphasizes necessary ground training between the 737NG and 737 MAX with FCC software version P12.1.2 or newer. Pilots may complete this training by accomplishing the applicable 737 MAX CBT provided by Boeing or an FAA-approved equivalent.

1.2.1 ATA 22 – Autoflight – FCC – MCAS:

- MCAS function description.
- Conditions for operation.
- Erroneous FCC trim commands.
- Flight deck alerting of the failure of the MCAS function.

1.2.2 ATA 22 – Autoflight – FCC – AFDS:

- Automatic AP disengagement.
- Temporary FD removal.
- AFDS pitch mode changes following stick shaker.
- Inhibiting of AP nose up trim.

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Exhibit 30: Training required based on the 2021 Flight Standardization Board Report [7].

1.2.3 ATA 22 – Autoflight – FCC – STAB OUT OF TRIM:

- Alert illumination logic (ground vs. flight).
- Revised NNC.

1.2.4 ATA 22 – Autoflight – FCC – SPEED TRIM FAIL:

- Function of the SPEED TRIM FAIL light.
- Revised NNC.

1.3 Training on the following bullet points that emphasize Boeing-recommended procedures. Pilots may complete this training by accomplishing the applicable 737 CBT provided by Boeing or an FAA-approved equivalent.

1.3.1 737 Manual Trim Operation:

- Manual stabilizer trim operation.
- Manual stabilizer trimming techniques.
- Effects of airspeed and aerodynamic loads on manual stabilizer trim operation.

1.3.2 737 Unreliable Airspeed – Determining a Reliable Airspeed:

- Recognition of flight deck effects of an unreliable airspeed condition.
- Memory pitch and thrust settings associated with the NNC.
- Determination of reliable airspeed indication.

2. FLIGHT TRAINING

Training is required to be conducted in a 737 MAX Level C or D FFS. The following bullet points emphasize the objectives of each maneuver. This training applies to pilots flying the 737 MAX, or conducting 737NG/737 MAX MFF. A 737NG Level C or D FFS may be used for some conditions where noted below.

2.1 Demonstration of MCAS activation accomplished by each pilot acting as PF.

2.1.1 MCAS activation during an impending stall (or full stall) and recovery demonstration during manual flight in a clean configuration.

2.1.2 Demonstrate MCAS activation stabilizer trim responses:

- Stabilizer trim in the nose down direction when above threshold AOA for MCAS activation during stall.
- Stabilizer trim in the nose up direction when below threshold AOA for MCAS activation during recovery.

2.2 Runaway stabilizer condition requiring use of manual stabilizer trim accomplished by each pilot acting as PF.

2.2.1 Runaway stabilizer training as described in subparagraph 9.2.2.5.

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Exhibit 31: Training required based on the 2021 Flight Standardization Board Report [6].

2.2.2 Operation of each manual trim technique (as defined by Boeing).

2.2.3 This training can be completed in a 737 MAX or 737NG FFS.

2.3 Use of manual stabilizer trim during approach, go-around, and level off accomplished by each pilot acting as PF.

2.3.1 Use of manual stabilizer trim as described in subparagraph 9.2.2.4.

2.3.2 This training can be completed in a 737 MAX or 737NG FFS.

2.4 A Cross-FCC Trim Monitor activation demonstration accomplished by either pilot acting as PF.

2.4.1 Condition must terminate in a landing in order to demonstrate the updated STAB OUT OF TRIM light functionality.

2.5 Erroneous high AOA during takeoff that leads to an unreliable airspeed condition accomplished by either pilot acting as PF.

2.5.1 Demonstrates flight deck effects (i.e., aural, visual, and tactile) associated with the failure.

2.5.2 Fault occurring during the takeoff procedure.

2.5.3 Must include a go-around or missed approach flown with erroneous high AOA condition.

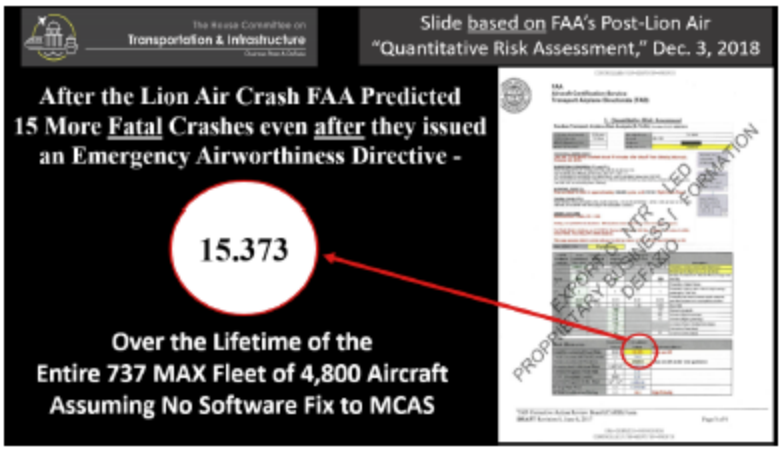
2.5.3.1 Special emphasis placed on FD behavior biasing out of view upon selecting takeoff/go-around (TO/GA).

Page 72 of 72

Exhibit 32: Training required based on the 2021 Flight Standardization Board Report [6].

(R-TARA), that was based on the TARAM method of analysis regarding the risk to the 737 MAX fleet from continued operations.[1239] The analysis was reviewed by the FAA's Seattle Aircraft Certification Office's Corrective Action Review Board (CARB) during a presentation on December 11, 2018, titled, "Maneuver Characteristics Augmentation System (MCAS) response to Angle of Attack (AOA) failed high."[1240]

The analysis was based on the assumption that only one out of 100 pilots would fail to react properly to uncommanded MCAS activation resulting in Stabilizer Trim Runaway.[1241] This seems to be a gross over estimation that predicted 99 out of every 100 pilots would correctly respond to this scenario, given the fact that one of Boeing's own test pilots failed to respond quickly enough in a simulator test. It seems the number of potential future accidents without a fix to MCAS may have been much higher than these predictions assumed.



Nevertheless, the results of the TARAM analysis indicated that even with the FAA's Emergency AD, but without a fix to MCAS, there could be more than 15 fatal 737 MAX crashes over the estimated 30-year lifetime of the fleet, then estimated to be 4,800 aircraft, resulting in over 2,900 deaths.[1242] Statistically this meant that the FAA was predicting there would be one fatal 737 MAX accident every two years for the next 30 years—or one fatal accident roughly every 24 months for the next 360 months. The FAA assumed that these potential future crashes would result in the loss of life for everyone on board the planes and some bystanders on the ground as well.[1243] However, they also estimated that Boeing would

[1239] Ibid., p. 167.
[1240] Federal Aviation Administration, TAD Corrective Action Review Board Presentation Form, "Title: Maneuver Characteristics Augmentation System (MCAS) response to Angle of Attack (AOA) failed high," 18-PAD-0048, December 11, 2018, BATES Number FAA-DEFAZIO-000028834 – 000028842, p. 165 -173, accessed here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg40697/pdf/CHRG-116hhrg40697.pdf
[1241] FAA briefing to Committee staff, December 4, 2019.
[1242] FAA briefing to Committee staff, December 4, 2019, and Federal Aviation Administration, TAD Corrective Action Review Board Presentation Form, "Title: Maneuver Characteristics Augmentation System (MCAS) response to Angle of Attack (AOA) failed high," 18-PAD-0048, December 11, 2018, BATES Number FAA-DEFAZIO-000028834 – 000028842, p. 167, accessed here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg40697/pdf/CHRG-116hhrg40697.pdf
[1243] Federal Aviation Administration, TAD Corrective Action Review Board Presentation Form, "Title: Maneuver Characteristics Augmentation System (MCAS) response to Angle of Attack (AOA) failed high," 18-PAD-0048, December 11, 2018, BATES Number FAA-DEFAZIO-000028834 – 000028842, p. 167, accessed here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg40697/pdf/CHRG-116hhrg40697.pdf (Note: The Injury Ratio factor of 1.05 means the loss of 5 bystanders for every 100 airplane occupant losses.)

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Exhibit 33: FAA determined likelihood for future crash occurrence assuming no fix [4].

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FAA
Aircraft Certification Service
Transport Airplane Directorate (TAD)

1. Quantitative Risk Assessment

Random Transport Airplane Risk Analysis (R-TARA) Version 2.4.2 10/20/2016

COS Item Number(s)	2016-xxxx	Airplane Model	737 MAX
COS SI Number	16-SI-xx	Branch	AIR-780
MSAD Event Number		Engineer	[redacted]
MSAD SI Number		Analysis Date	12/3/2018

CONDITION UNDER STUDY
Lion Air 737-8 (MAX) crashed about 10 minutes after takeoff from Jakarta, Indonesia, October 29, 2018.

SUSCEPTIBLE CONDITION (CP_1 and CP_2)
Describe any particular configuration that puts the airplane at risk.
If all airplanes are affected, all the time, then $CP_1 = CP_2 = 1$.
CP_1 represents the probability of a latent failure, and is calculated below (see Cell F42).
CP_2 represents the probability of flying in a critical condition (including cargo loading, passenger configurations, fuel load, etc. but excluding latent failures).

INITIATING EVENT (F)
One accident to date in approximately 135,980 cycles and 372,754 flight hours flown.

CAUSAL CHAIN (CP_3)
Describe how the event leads to the unsafe outcome. CP_3 is the probability t at the e ent will lead to he unsafe outcome, for airplanes that are flying in the susceptible condition.

UNSAFE OUTCOME
Uncontrolled Crash, IR = 1.05

Adding not-yet-delivered airplanes 250 airplanes now, 400 average over the contract program.

Per Flight Global database as of 11/25/18, Boeing ha[illegible] 264 Max airplanes, and orders for 4554, total of 4818. Rounding off to 4800 airplanes.

This page assumes interim action reduces the risk by a factor of 10). It still need HP NPRM or IAR.

Airplane flies in susceptible condition CP = $CP_1 \times CP_2$

Airplane experiences event (system failure, pilot input, turbulence, etc.) F

Event leads to unsafe outcome (in-flight breakup, crash, etc.) CP_3

(A)

(B)

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1

2 ***Exhibit 34: FAA analysis under-reported the number of anticipated aircraft (A) and included***
3 ***assumptions (B) with regards to interim risk-reduction (highlights by author, from Exhibit 33).***

4

5 Note: A higher resolution of this page was found at this URL: https://tinyurl.com/2p97afrk

3.10 Estimates Based on Engineering Judgment

An important element of good analysis is ensuring that, when practicable, all judgments and estimates are based on empirical data—data based on observation, test, or experience. When sufficient empirical data is lacking, accepted engineering practices will need to be used to determine the "best estimate" of the actual quantitative values needed for risk determination. If you are an analyst making such estimates, you should document the basis for your estimates on the risk-analysis worksheet. This information can then be considered when determining the appropriate response for the potential unsafe condition. Intentionally conservative estimates or arbitrarily inflated risk factors, to account for uncertainty, will result in less-effective overall risk management. Conservative estimates and the resulting conservative risk values will cause safety issues with lower actual risk to be prioritized and addressed at the same time as, or even ahead of, safety issues with higher actual risk. Conversely, unrealistically optimistic risk values should be avoided for the same reason.

Good quantitative analysis is meant to provide the best estimate of risk based on available information. You should not avoid quantitative analysis simply because the data are incomplete. Risk analyses invariably depend on sound engineering judgment, even though this introduces an element of subjectivity into the analysis. You should document uncertainties in the details of the analysis on the risk-analysis worksheet. The CARB needs complete information to consider when determining the appropriate response for each potential unsafe condition.

3.11 Validation

To ensure the quality of the risk-analysis process, and whenever possible, compare the risk values produced by an analysis against the historical record associated with the condition under study and its effects to see if the calculated values appear reasonable. If the risk values are considerably higher or lower than expected based on knowledge of the historical impact of the issue, review the data, estimates, and associated technical assumptions used. Determine whether all considerations were properly assessed and make sure that overly conservative or overly optimistic assumptions were not introduced. It may be possible and necessary in some cases to apply the data, estimates, and associated technical assumptions in the analysis to predict past events, then compare the result to the actual historical record to validate the predicted risk values.

You should not adjust risk variables or values for the sole purpose of making the result match individual or commonly held (but unproven) perceptions, or to align with past, qualitatively based safety decisions.

Exhibit 35: TARAM requires estimates based on available data and engineering judgment as well as validation to confirm/refute the assumptions (highlights by author) [8].

4.2.2 Determining the Type of Risk Analysis (Constant Failure Rate or Wear-out)

Failures can be categorized into three types:

- **Early failures**—those situations where parts are more likely to fail early in their life. (These failures are sometimes referred to in risk-analysis literature as "infant mortality" failures.)
- **Random (constant-rate) failures**—in which parts are equally liable to fail, whatever their age. Fan-blade failures due to bird strike are an example of random failures.
- **Wear-out failures**—the category of failures that are increasingly likely as parts age.

Although the risk-analysis formulas are similar for each type, the complexity of determining the frequency of occurrence varies significantly enough between the constant failure rate (random) and the logarithmic failure models (early and wear-out) that the types are treated separately in this handbook.

Early-failure distributions are rare in transport-airplane COS and are not discussed separately in this handbook. If an early-failure issue is found, it can be analyzed and the associated risk determined using the wear-out guidance and worksheet. However, be careful to include in the analysis only the sub-fleet of airplanes known (or estimated) to have the early-failure condition. Contact the FAA TAD Safety Management Branch, ANM-117, if necessary, for additional guidance and/or information regarding early-failure analysis.

If the analyst isn't sure of the failure mode involved, and the failure distribution of the condition under study is unknown, the ASE can perform a Weibull analysis (or use another suitable analytical method) to determine the failure mode, and thus the associated risk analysis methodology necessary. The slope of the Weibull plot, beta (β), indicates which class of failures is present:

- $\beta < 1.0$ indicates early-failure distribution
- $\beta \cong 1.0$ means random-failure distribution (independent of age)
- $\beta > 1.0$ indicates wear-out-failure distribution

Many commercial, off-the-shelf software packages are available to simplify analysis. The type-certificate holder may also be able to provide results of a Weibull or log-normal analysis performed in the past to aid in the failure-type determination.

See Chapter 5 of this handbook for guidance in assessing the risk associated with wear-out concerns.

The units of time used in the analysis are chosen to attain the best correlation with the data. An understanding of the physics of the problem under study often simplifies this selection. For example, the unit of time used in evaluating structural-fatigue problems is usually flight cycles. Flight hours are another common time unit. Other problems, such as corrosion, may be related most directly to chronological time, so the best Weibull units of time in those cases are calendar hours, days, or years. After a unit of time is chosen, it must be used consistently throughout the risk analysis.

4.3 Unsafe Outcomes

4.3.1 General Guidance

You should clearly identify the foreseeable airplane-level outcome(s) with a known injury ratio closest in the causal chain to the condition under study. Identifying the closest outcomes with a known injury ratio will minimize the analytical complexity and data requirements in the risk analysis, as illustrated in Figure 3, and will also tend to improve the accuracy of the analysis.

1

2 ***Exhibit 36: TARAM risk analyses types [8].***

6 Risk Management

This section provides guidance for applying results of the risk analysis to risk-management decision-making as part of the Order 8110.107 process.

6.1 Fail-Safe Design

The philosophy of fail-safe design has been an important part of ensuring transport-airplane safety for more than 50 years. A tenet of that philosophy is that the airplane must be designed in such a way that no single failure can prevent continued safe flight and landing, regardless of the probability of the single failure. Some exceptions to this philosophy are made out of necessity at the time of certification, e.g., engine and landing gear parts that have safe-life limits. Other exceptions are made in unusual circumstances at the time of certification, such as when the FAA determines, based on experienced engineering judgment, that such a failure is not a practical possibility (reference AC 25.1309-1A paragraph 7.g.).

The fail-safe design philosophy in the airworthiness rules is expressed in qualitative terms, and compliance is found based on engineering and operational judgment. As a result, it is not feasible to define or correlate the fail-safe 'single failure' criteria directly to the quantitative risk values and guidance in the TARAM. The determination of whether a discovered single failure is a violation of the fail-safe design philosophy, and therefore unsafe, must be based on experienced engineering and operational judgment.

However, if a single-failure condition discovered in service:

- can lead directly to an unsafe outcome with an injury ratio greater than 0.10 (10%), and
- with all known operational/environmental factors, conditional probability (single failure to unsafe outcome) is greater than 0.10 (10%)

then, the failure condition should be suspected of violating fail-safe design requirements and evaluated based on the criteria associated with fail-safe principles. If you determine that the condition violates the fail-safe philosophy, you should consider the condition unsafe regardless of the calculated TARAM uncorrected fleet or individual risk values. However, the urgency of corrective action, and the adequacy of the corrective action timeframe for single-failure issues, should be based on the associated TARAM 90-day fleet risk, control-program fleet risk, and control-program individual-risk values.

Note: For the purpose of TARAM uncorrected-risk analyses, unless the structure is certified as "safe life" [14 CFR 25.571(c)], fatigue cracks are not automatically considered "single failures."

6.2 Risk-Level Guidance

Table 3 provides risk-level guidance for corrective-action decision-making. These values are guidance for the range of risk that may require corrective action. Per 14 CFR part 21, the determination that an airplane design or feature is safe, or that an airplane is safely operable, is an important function of the Administrator, yet the Administrator has a great deal of inherent flexibility and latitude when making safety determinations. The guidance in Table 3 does not define or limit the Administrator's prerogative to make such safety decisions.

The risk values in Table 3 are not risk thresholds. Confidence in the analytically derived values can vary widely, and that confidence must be considered in risk-management decisions. Factors other than risk also are considered in safety decision-making, and the Table 3 values do not limit the scope or weight of those other considerations.

Although some of the TARAM risk values and associated risk-level guidance are expressed in terms of fatalities, they should not be viewed as predictive values. The TARAM risk values and risk-level guidance represent a "level" or "range" and are not expectations of actual events.

Control-program fleet risk-level guidance is used in conjunction with a general philosophy to *correct unacceptable risk as soon as reasonably practical*. The correction-as-soon-as-reasonably-practical philosophy is necessary because the TARAM does not address the

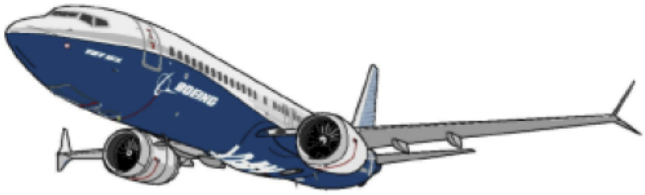
Exhibit 37: Requirement of 'fail-safe' design [8].

November 7, 2017, also confirmed Boeing's decision to defer fixing the AOA Disagree alert until the 737 MAX 10 entered service.[772]

Boeing considered notifying airlines who were flying the 737 MAX about the defective AOA Disagree alert, and even prepared a Fleet Team Digest on the issue.[773] These digests provide "in-service issues," including economic and safety-related information to Boeing's customers.[774] Ultimately, however, Boeing never sent the digest,[775] and Boeing's customers and MAX pilots remained unaware of the inoperable AOA Disagree alerts until **after** the Lion Air crash.

The Committee's investigation confirmed that Boeing continued to mislead MAX pilots and Boeing customers for more than a year after Boeing learned about the lack of the AOA Disagree alert's functionality in the majority of the 737 MAX fleet. For instance, Boeing provided a Flight Crew Operations Manual (FCOM) on the 737 MAX to P.T. Lion Mentari, the parent company of Lion Air,[776] dated August 16, 2018, a full year after Boeing first learned that the AOA Disagree alert was not working on most 737 MAX aircraft.[777] Yet the FCOM still contained a description of [illegible][778]

BOEING



737-8

Flight Crew Operations Manual

P. T. Lion Mentari

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BOEING PROPRIETARY

Document Number D6-27370-MAX-MLI
Revision Number: 4
Revision Date: August 16, 2018

Exhibit 38: Boeing's Flight Crew Operations Manual (pg. 132) [4].

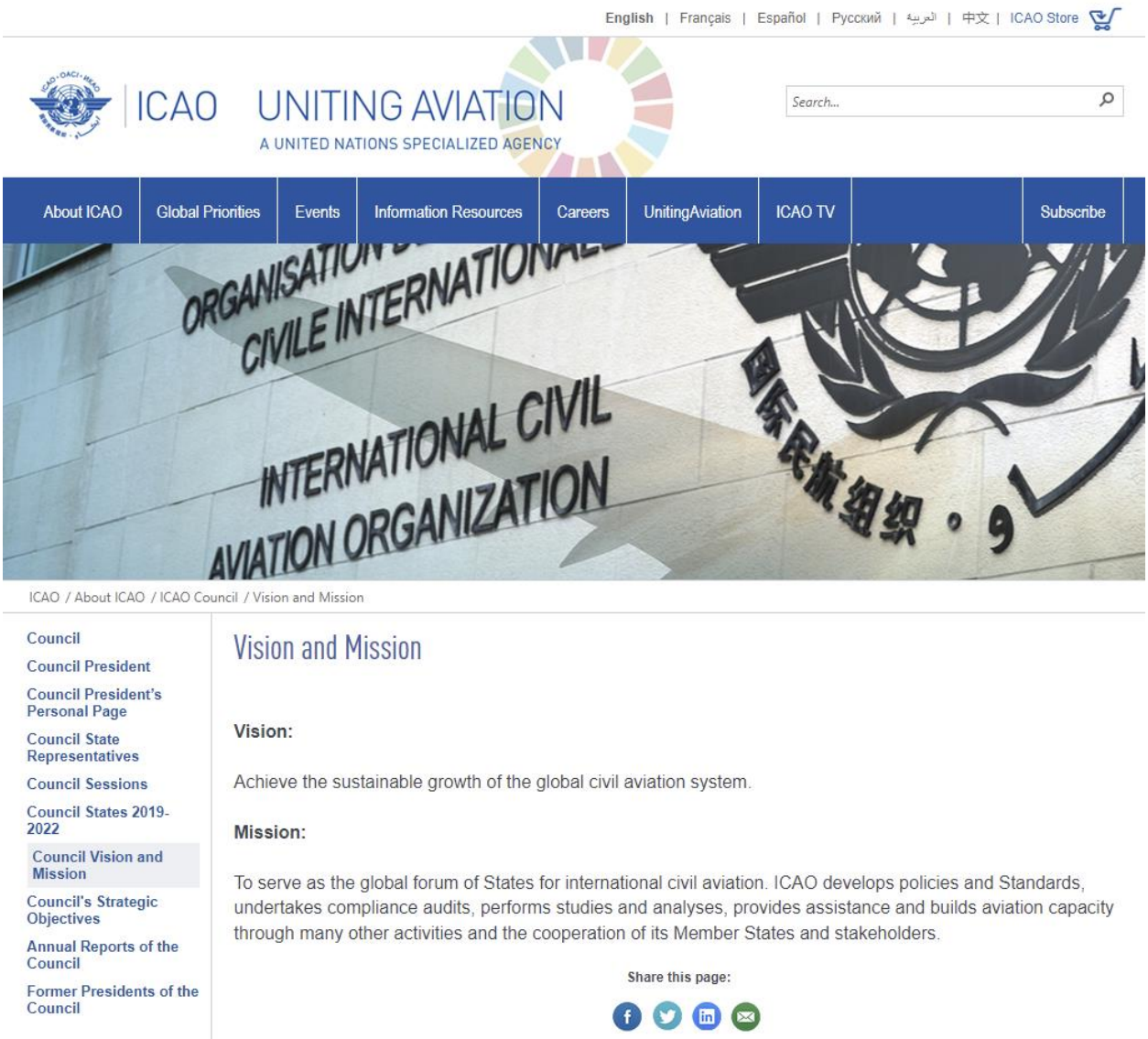


Exhibit 39: International Civil Aviation Organization (ICAO).

CONVENTION ON INTERNATIONAL CIVIL AVIATION

PREAMBLE

WHEREAS the future development of international civil aviation can greatly help to create and preserve friendship and understanding among the nations and peoples of the world, yet its abuse can become a threat to the general security; and

WHEREAS it is desirable to avoid friction and to promote that cooperation between nations and peoples upon which the peace of the world depends;

THEREFORE, the undersigned governments having agreed on certain principles and arrangements in order that international civil aviation may be developed in a safe and orderly manner and that international air transport services may be established on the basis of equality of opportunity and operated soundly and economically;

Have accordingly concluded this Convention to that end.

PART I. AIR NAVIGATION

CHAPTER I

GENERAL PRINCIPLES AND APPLICATION OF THE CONVENTION

Article 1

Sovereignty — The contracting States recognize that every State has complete and exclusive sovereignty over the airspace above its territory.

Article 2

Territory — For the purposes of this Convention the territory of a State shall be deemed to be the land areas and

Exhibit 40: Preamble to the 1944 International Aviation Convention [9].

Article 44

Objectives

The aims and objectives of the Organization are to develop the principles and techniques of international air navigation and to foster the planning and development of international air transport so as to:

(a) Insure the safe and orderly growth of international civil aviation throughout the world;

(b) Encourage the arts of aircraft design and operation for peaceful purposes;

(c) Encourage the development of airways, airports, and air navigation facilities for international civil aviation;

(d) Meet the needs of the peoples of the world for safe, regular, efficient and economical air transport;

(e) Prevent economic waste caused by unreasonable competition;

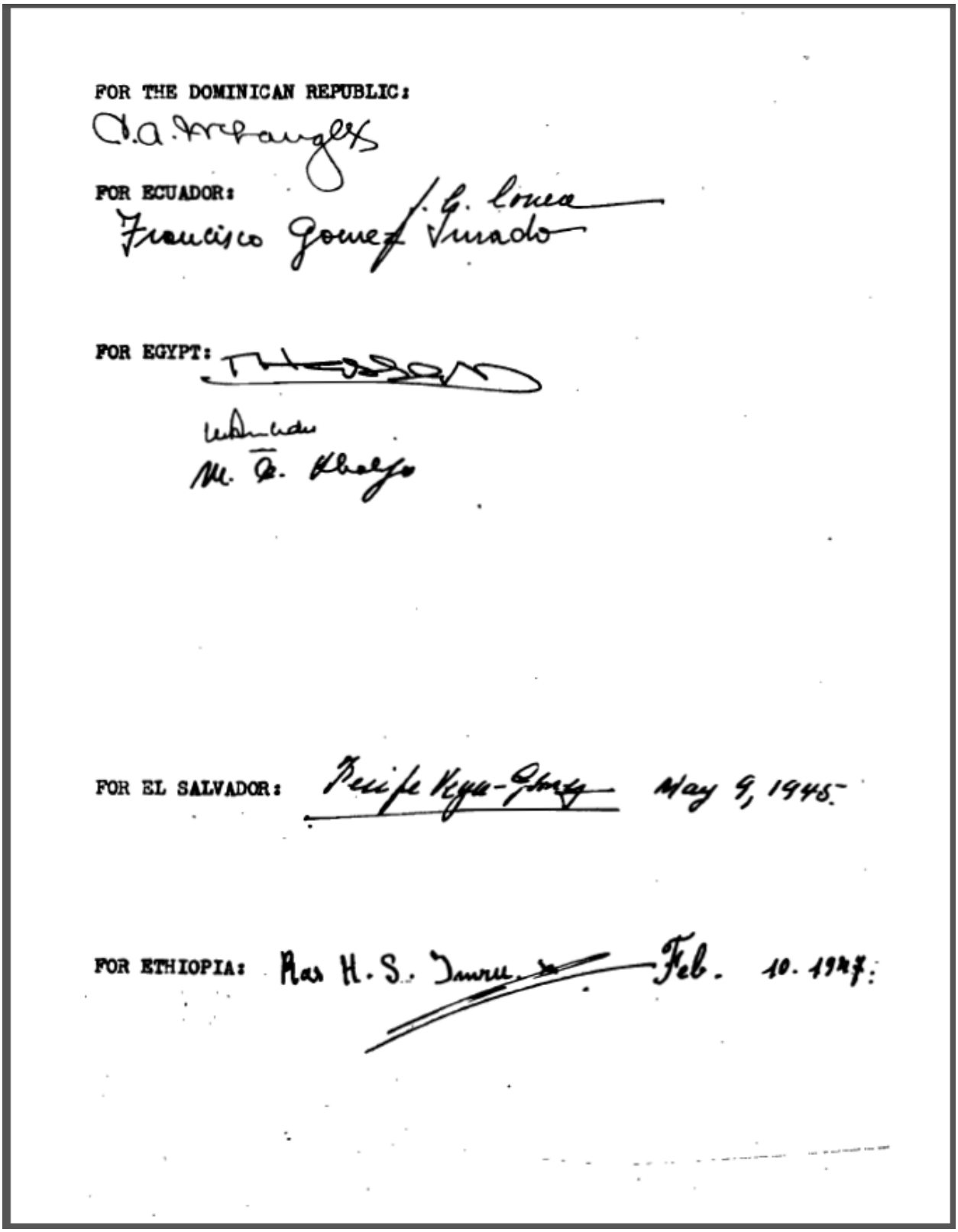
(f) Insure that the rights of contracting States are fully respected and that every contracting State has a fair opportunity to operate international airlines;

(g) Avoid discrimination between contracting States;

(h) Promote safety of flight in international air navigation;

(i) Promote generally the development of all aspects of international civil aeronautics.

Exhibit 41: Aims of ICAO per the 1944 Chicago convention [9].


FOR THE DOMINICAN REPUBLIC:

FOR ECUADOR:

FOR EGYPT:

FOR EL SALVADOR: May 9, 1945.

FOR ETHIOPIA: Feb. 10. 1947.

Exhibit 42: Ethiopia was a signatory to Chicago 1944 in 1947 [9].

State	Date of deposit of instrument of ratification or notification of adherence (A)
Djibouti	30 June 1978 (A)
Dominica	14 March 2019 (A)
Dominican Republic	25 January 1946
Ecuador	20 August 1954
Egypt	13 March 1947
El Salvador	11 June 1947
Equatorial Guinea	22 February 1972 (A)
Eritrea	17 September 1993 (A)
Estonia	24 January 1992 (A)
Eswatini	14 February 1973 (A)
Ethiopia	1 March 1947
Fiji	5 March 1973 (A)
Finland	30 March 1949 (A)
France	25 March 1947
Gabon	18 January 1962 (A)
Gambia	13 May 1977 (A)
Georgia	21 January 1994 (A)
Germany (2)	9 May 1956 (A)
Ghana	9 May 1957 (A)
Greece	13 March 1947
Grenada	31 August 1981 (A)
Guatemala	28 April 1947
Guinea	27 March 1959 (A)
Guinea-Bissau	15 December 1977 (A)
Guyana	3 February 1967 (A)
Haiti	25 March 1948
Honduras	7 May 1953
Hungary	30 September 1969 (A)
Iceland	21 March 1947
India	1 March 1947
Indonesia	27 April 1950 (A)
Iran (Islamic Republic of)	19 April 1950

Exhibit 43: Excerpt from ICAO website noting dates Ethiopia and Indonesia signed on to the 1944 Chicago Convention (highlights by author) [10]. Access list here: https://tinyurl.com/bdz3tzaa

Selected Programs, Products and Services

Boeing Commercial Airplanes	Stanley A. Deal, Executive Vice President; President and Chief Executive Officer, Boeing Commercial Airplanes, Seattle, Washington, USA	
737 Family **737-7**  **737-8**  **737-9**  **737-10** 	Boeing is continuing to make progress on the global safe return to service of the 737 MAX. Since the U.S. Federal Aviation Administration's approval to return the 737 MAX to operations in November 2020, Boeing has delivered 272 737 MAX airplanes, and airlines have returned more than 200 previously grounded airplanes to service. With 35 airlines operating the 737 MAX, they have flown nearly 300,000 safe revenue flights totaling 720,000 flight hours. The 737 program continues to progress toward a production rate of 31 airplanes per month in early 2022. The first 737-8 delivery took place in 2017. We currently anticipate entry into service of the 737-7 in 2022 and the first delivery of the 737-10 in 2023, dependent on regulatory approval.	*Orders:* *14,291 (all 737s)** *4,035 (737 MAXs)** *Deliveries:* *10,877 (all 737s)** *659 (737 MAXs)**
747-8 Family **747-8 Intercontinental**	The 747-8 Intercontinental and the 747-8 Freighter are the last-generation airplanes of the iconic Boeing 747 family. The airplanes feature new wings with raked wingtips and more fuel efficient	2012, operates in the 400- to 500-seat market, seating 410 passengers in a typical three-class configuration (66 more than the 747-400).

Exhibit 44: Boeing as of 2021 produced 659 737 MAX planes and projected a total of over 4,000 MAX planes in total [2].

Note 13 – Liabilities, Commitments and Contingencies

Accrued Liabilities

Accrued liabilities at December 31 consisted of the following:

	2021	2020
Accrued compensation and employee benefit costs	**$6,573**	$7,121
737 MAX customer concessions and other considerations	**2,940**	5,537
Department of Justice agreement liability		744
Environmental	**605**	565
Product warranties	**1,900**	1,527
Forward loss recognition	**2,014**	1,913
Income taxes payable	**5**	43
Current portion of lease liabilities	**268**	268
Other	**4,150**	4,453
Total	**$18,455**	$22,171

737 MAX Grounding

In 2019, following two fatal 737 MAX accidents, the Federal Aviation Administration (FAA) and non-U.S. civil aviation authorities issued orders suspending commercial operations of 737 MAX aircraft. Deliveries of the 737 MAX were suspended following these orders. Deliveries in the U.S. resumed in late 2020 following rescission by the FAA of its grounding order. In addition, several other non-U.S. civil aviation authorities, including the Brazilian National Civil Aviation Agency, Transport Canada, and the European Union Aviation Safety Agency have subsequently approved return of operations, allowing us to resume deliveries in those jurisdictions. The Civil Aviation Administration of China issued an airworthiness directive in the fourth quarter of 2021 outlining actions required for airlines to return to service. We expect 737 MAX deliveries to China to resume in 2022, subject to final regulatory approvals, although risk remains around the timing and rate of those deliveries. Over 185 countries have approved the resumption of 737 MAX operations. The 737 MAX remains grounded in a small number of non-U.S. jurisdictions.

We have gradually increased production rates in 2020 and 2021 and continue to expect to increase the production rate to 31 per month by early 2022, as well as implement further gradual production rate increases in subsequent periods based on market demand and supply chain capacity.

We produced at abnormally low production rates in 2020 and 2021 and expensed abnormal production costs of $1,887 and $2,567 during the years ended December 31, 2021 and 2020. We do not expect the remaining abnormal costs related to the 737 MAX to be significant and expect most of the remainder to be incurred in early 2022.

In 2021, we delivered 245 aircraft. We have approximately 335 airplanes in inventory as of December 31, 2021 and we anticipate delivering most of these aircraft by the end of 2023. We continue to work with customers who have requested to defer deliveries or to cancel orders for 737 MAX aircraft, and we are remarketing and/or delaying deliveries of certain aircraft included within inventory. In the event that we are unable to resume aircraft deliveries in China and/or ramp up deliveries consistent with our assumptions, our expectation of delivery timing and our expectation regarding future gradual production rate increases could be impacted.

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Exhibit 45: Liabilities associated with the 737 MAX crashes and grounding [2] (highlights by author).

We have also recorded additional expenses of $175, $416, and $328 due to the 737 MAX grounding during 2021, 2020, and 2019, respectively. The expenses include costs related to storage, inventory impairment, pilot training, and software updates.

The following table summarizes changes in the 737 MAX customer concessions and other considerations liability during 2021 and 2020.

	2021	2020
Beginning balance – January 1	**$5,537**	$7,389
Reductions for payments made	**(2,535)**	(2,188)
Reductions for concessions and other in-kind considerations	**(48)**	(162)
Changes in estimates	**(14)**	498
Ending balance – December 31	**$2,940**	$5,537

The liability balance of $2.9 billion at December 31, 2021 includes $2.2 billion of contracted customer concessions and other liabilities and $0.7 billion that remains subject to negotiation with customers. The contracted amount includes $1.0 billion expected to be liquidated by lower customer delivery payments, $1.0 billion expected to be paid in cash and $0.2 billion in other concessions. Of the cash payments to customers, we expect to pay $0.8 billion in 2022. The type of consideration to be provided for the remaining $0.7 billion will depend on the outcomes of negotiations with customers.

Environmental

The following table summarizes environmental remediation activity during the years ended December 31, 2021 and 2020.

	2021	2020
Beginning balance – January 1	**$565**	$570
Reductions for payments made	**(59)**	(42)
Changes in estimates	**99**	37
Ending balance – December 31	**$605**	$565

The liabilities recorded represent our best estimate or the low end of a range of reasonably possible costs expected to be incurred to remediate sites, including operation and maintenance over periods of up to 30 years. It is reasonably possible that we may incur charges that exceed these recorded amounts because of regulatory agency orders and directives, changes in laws and/or regulations, higher than expected costs and/or the discovery of new or additional contamination. As part of our estimating process, we develop a range of reasonably possible alternate scenarios that includes the high end of a range of reasonably possible cost estimates for all remediation sites for which we have sufficient information based on our experience and existing laws and regulations. There are some potential remediation obligations where the costs of remediation cannot be reasonably estimated. At December 31, 2021 and 2020, the high end of the estimated range of reasonably possible remediation costs exceeded our recorded liabilities by $1,094 and 1,095.

Exhibit 46: Liabilities associated with the 737 MAX crashes and grounding [4].

APPENDIX A

Dr. Storesund CV & Consulting Resume

Storesund Consulting (President & CEO); 154 Lawson Road, Kensington, CA 94707; Phone: 510-526-5849; Email: rune@storesundconsulting.com (2005 to Present)

Storesund Construction Inc. (President & CEO); 154 Lawson Road, Kensington, CA 94707; Phone: 510-526-5849; Email: rune@sc-svcs.com (2015 to Present)

NextGen Mapping, Inc. (President & CEO); 154 Lawson Road, Kensington, CA 94707; Phone: 510-526-5849; Email: rune@ngm-inc.com (2016 to Present)

SafeR^3 non-profit, (Director & Co-Founder); 1709 Hopkins Street, Berkeley, CA 94707; Phone: 510-526-5849; Email: rune@safer.world (2020 to Present)

Center for Catastrophic Risk Management (Executive Director); University of California, Berkeley; 8th Floor Barrows Hall, Berkeley, CA 94702; Phone: 510-225-5389; Email: rune@berkeley.edu (2012 to Present)

PROFESSIONAL PREPARATION

Dr. Eng	Civil Systems, University of California at Berkeley, 2009
M.O.T.	University of California at Berkeley, 2007
M.S.	Geotechnical Engineering, University of California at Berkeley, 2002
B.S.	Civil & Environmental Engineering, University of California at Berkeley, 2000
B.A.	Anthropology, University of California at Santa Cruz, 2000

PROFESSIONAL REGISTRATIONS

California, Civil Engineer, RCE 64473
California, Geotechnical Engineer, GE 2855
Louisiana, Civil Engineer, RCE 35034
Hawaii, Civil Engineer, PE 1549
Washington, Civil Engineer, PE 52924
California Safety Assessment Program Engineer

NATIONAL SUBJECT MATTER EXPERT ENGAGEMENTS

Klamath River Dam Removals, Del Norte County Technical Expert, 2019 – Present
Oroville Dam Ad-Hoc Oversight Committee, California Legislature, 2018-present
Dam Safety Culture Development, Assemblyman Gallagher (California Legislature), 2018-present
California Dam Safety Culture, Senator Jim Nielsen (California Legislature), 2018-present
South Platte River and Harvard & Weir Gulch Ecosystem Restoration and Flood Risk Management, U.S. Army Corps of Engineers Independent External Peer Review; 2018
Oso Landslide Investigation, Attorney General of State of Washington, 2014-2018
South Platte River and Harvard & Weir Gulch Ecosystem Restoration and Flood Risk Management, U.S. Army Corps of Engineers Independent External Peer Review; 2018
McCook Levee Small Flood Risk Management & Environmental Assessment; U.S. Army Corps of Engineers Independent External Peer Review; 2017
Houston Ship Channel Expansion Channel Improvement Project, Harris, Chambers, and Galveston Counties, Texas; U.S. Army Corps of Engineers Independent External Peer Review; 2017-2018

MEDIA ENGAGEMENTS/CONSULTATIONS

New York Times Science News, John Schwartz
CBS News – San Francisco, Kathleen Seccombe
KQED News, Peter Jon Shuler
KQED Radio Science News, Lauren Sommer
KQED Radio Water & Infrastructure News, Dan Brekke
NBC Bay Area News Investigative Unit, Jaxon Van Derbeken
UC Berkeley Media Relations, Sarah Yang

PROFESSIONAL AFFILIATIONS

American Geophysical Union (AGU)
ASCE GEO-Institute
ASCE Leadership and Management Committee
- Chair, 2010-2011
- Full Committee Member, 2009-Present
- Corresponding Member, 2003-2009

ASCE Region 9 Governor, 2019 - Present
ASCE San Francisco Section
- President 2011-2012
- Tsunami Hazard Committee Chair, 2010-Present
- President Elect 2009-2011
- Vice President 2010 – 2011
- Geotechnical Society Committee, 2000-2006
- Infrastructure Report Card Committee, 2001-2003
- Water Resources Group
    - Director, 2010-2011
    - Chair, 2009-2010
- Younger Member Forum
    - President 2003-2004
    - Board Member, 2000-2004

National Society of Professional Engineers, 2005-Present
California Society of Professional Engineers, 2005-Present
Project Management Institute, 2005-2012
UC Berkeley Geotechnical Engineering Society, 2002-Present
UC Berkeley Engineering Alumni Society, 2009-Present

TECHNICAL PEER REVIEWER ENGAGEMENTS

ASCE Press (book peer reviews)
Association of Engineering Geologists (AEG), Technical Paper Peer Reviewer
Hydrology and Earth System Sciences (HESS), Technical Paper Peer Reviewer
National Academy of Forensic Engineers (NAFE), Technical Paper Peer Reviewer
Ocean Engineering: An International Journal of Research and Development, Technical Paper Peer Reviewer
Remote Sensing Journal, Technical Paper Peer Reviewer
Safety Science, Technical Paper Peer Reviewer

HONORS AND AWARDS

ASCE Edmund Friedman Young Engineer Award for Professional Achievement, 2013
H.J. Brunnier Award, San Francisco Section ASCE, 2013
President's Award, San Francisco Section ASCE, 2012
Outstanding ASCE Younger Member Forum Officer, ASCE Region 9, 2009
ASCE WRYMC Outstanding Engineer in the Private Sector, 2008
CELSOC Graduate Scholarship, 2007
ASCE San Francisco Section Outstanding YMF Civil Engineer, 2004
ASCE Golden Gate Branch Scholarship, 1999, 2000
CELSOC Undergraduate Scholarship, 2000

COURSE INSTRUCTION

CEE 24:	Freshman Seminars in Environmental Engineering, Fall 2007, Spring 2008
CEE 99:	Undergraduate Independent Research, Spring 2002
CEE 180:	Engineered Systems, Spring 2002, Spring 2008
CEE 199:	Undergraduate Independent Research, Fall 2006
CEE290A:	Human and Organizational Factors, Spring 2006, Spring 2008
ENG36:	Engineering Mechanics, Fall 2005
LAEP 222:	Hydrology for Planners, Spring 2007
LAEP 227:	River Restoration, Fall 2008
LAEP 201:	Ecological Factors in Urban Landscape Design, Fall 2011

MENTORING & RESEARCH COLLABORATION
Visiting Scholars

Chen, Bing. Professor of Civil Engineering, Director of NRPOP Laboratory, Faculty of Engineering and Applied Science, Memorial University, Canada. 2016-2017.

Ph.D. and M.S. w/thesis students:

Frykmer, Tove. PhD Candidate. "Adaptive command & control and collaboration within the Swedish crisis management." Copenhagen University. 2016.
Meland, Per Håkon. PhD Candidate. "How can cyber security be combined with traditional safety considerations in domain specific threat modelling techniques?" Norwegian University of Science and Technology. 2019-2020.
Nesse, Synnove. PhD Candidate. Center for Applied Research (SNF), Norwegian School of Economics. 2014.
Schafer, Kathleen. PhD Candidate. "Cal Fl(ood)-exit: an exploration of alternatives to the National Flood Insurance Program for the California," University of California, Davis. 2017 – 2020.
Tsesmetsis, Alexander. MS Candidate. Civil Systems Safety Culture. Norwegian University of Science and Technology. 2019.
Ye, Xudong. PhD Candidate. A new risk-human factor analysis method for oil spill response decision making. Memorial University, Canada. 2017-2020.

Research Collaboration:

NSERC CREATE training program in Persistent, Emerging, and Oil PoLlution management in cold marine and coastal Environments (PEOPLE CREATE), funded by Natural Science and Engineering Research Council of Canada (NSERC) Collaborative Research and Training Experience Grant (CREATE), $1.65M, 2019-2026

Improved Decanting and Oily Waste Management Strategies for Marine Oil Spill Response, Canada Oceans Protection Plan – Multi-Partner Research Initiative (MPRI), $2,687,400, 2018-2022

PEER-REVIEWED JOURNAL PUBLICATIONS/TECHNICAL PAPERS

Storesund, Rune. "Forensic Evaluation of Construction Noise and Vibrations Associated with an Urban Drainage Project." Journal of the National Academy of Forensic Engineers. In Press.

Storesund, Rune. "FE Evaluation of Hillside Excavation For a Construction Contract Dispute." Journal of the National Academy of Forensic Engineers. Vol 36, No. 1. June 2019.

Storesund, Rune. "Forensic Engineer Expert Communications: Lessons Learned from the March 2014 Oso Landslide Litigation." Journal of the National Academy of Forensic Engineers. Vol 35, No. 1. June 2018.

Ye XD*, Chen B, Lee K, Storesund R, Zhang BY. (2020) An improved offshore oil spill response decision making method based on the integration of human factor analysis and fuzzy preference evaluation. Environmental Pollution. 262 (2020): 114294 https://doi.org/10.1016/j.envpol.2020.114294 (IF = 5.714)

Ye XD*, Chen B, Lee K, Storesund R, Zhang BY. (2020) An enhanced simulation and optimization coupling approach for supporting marine oil spill responses. The 2020 Virtual Symposium of the LEaders in wAter anD watERshed Sustainability (the LEADERS Program) and the Network on Persistent, Emerging, and Organic PoLlution in the Environment (PEOPLE Network), August 31-Sepember 1, 2020.

Ye XD*, Chen B, Lee K, Storesund R, Zhang BY (2020) A multi-agent based multi-objective particle swarm optimization (MMPSO) for the optimal planning of an offshore oil decanting procedure. The Gulf of Mexico Oil Spill and Ecosystem Science Conference (GoMOSES) 2020, February 3-6, Tampa, USA

Ye XD*, Chen B, Storesund R, Lee K. (2019) A new offshore oil spill response decision making method based on human factor analysis and fuzzy preference evaluation. The 42nd Arctic and Marine Oil spill Program (AMOP) Technical Seminar on Environmental Contamination and Response, June 4-6, 2019, Halifax, Canada

Ye XD*, Chen B, Storesund R, Lee K. (2018) A new risk-human factor analysis method for oil spill response decision making. (2018). The 41th Arctic and Marine Oil spill Program (AMOP) Technical Seminar on Environmental Contamination and Response, October 2-4, 2018, Victoria, Canada

Ye XD, Chen B, Storesund R. (2017) Analysis of oil spill risk and human factors for response decision making. The PEOPLE 2017 Symposium of the Research and Training Network on Persistent and Emerging Organic Pollution in Cold and Coastal Environments (PEOPLE Network), October 16-17, 2017, St. John's, Canada

Roe, Emery, Robert G. Bea, Sebastiaan N. Jonkman, H. Faucher de Corn, Howard Foster, John Radke, Paul Schulman, and Rune Storesund. "Risk Assessment and management for interconnected critical infrastructure systems at the site and regional levels in California's Sacramento-San Joaquin Delta," International Journal of Critical Infrastructures, Vol 12, Nos 1/2, 2016.

Florsheim, Joan L., Chin, Anne, O'Hirok, Linda S., and Storesund, Rune. "Short-term post-wildfire dry-ravel processes in a chaparral fluvial system," 2015. "submitted for publication.

Kondolf, G. M., Anderson, Shannah D., Storesund, Rune, Tompkins, Mark, and Atwood, Paul. "Restoration Ecology Post-Project Appraisals of River Restoration in Advanced University

Instruction." The Journal of the Society for Ecological Restoration. Vol. 19, Issue 6, p. 696-700. 2011.

Storesund, Rune, Robert G. Bea, Yuli Huang. "Simulated Wave-Induced Erosion of the Mississippi River-Gulf Outlet Levees during Hurricane Katrina." Journal of Waterway, Port, Coastal, Ocean Engineering. Vol. 136, p. 177-189. 2010.

Bernhardt, M., Briaud, J.L., Kim, D., Leclair, M., Storesund, R., Lim, S.G., Bea, G.R., Rogers, J.D. (2011). "Mississippi River Levee Failures: June 2008 Flood." International Journal of Geoengineering Case Histories, http://casehistories.geoengineer.org, Vol.2, Issue 3, p. 127-162. doi: 10.4417/IJGCH-02-02-03.

Briaud, J.-L., H.C. Chen, A.V. Govindasamy, and R. Storesund, "Levee Erosion by Overtopping in New Orleans During the Katrina Hurricane," ASCE, Journal of Geotechnical and Geoenvironmental Engineering. Vol. 134, p. 618, 2008.

Seed et al. "New Orleans and Hurricane Katrina. I: Introduction, Overview, and the East Flank." Journal of Geotechnical Geoenvironmental Engineering. Vol. 134, p. 701-717.2008.

Seed et al. "New Orleans and Hurricane Katrina. II: The Central Region and the Lower Ninth Ward." Journal of Geotechnical Geoenvironmental Engineering. Vol. 134, p. 718-739.2008.

Seed et al. "New Orleans and Hurricane Katrina. III: The 17th Street Drainage Canal." Journal of Geotechnical Geoenvironmental Engineering. Vol. 134, p. 740-761.2008.

Seed et al. "New Orleans and Hurricane Katrina. IV: Orleans East Bank (Metro) Protected Basin." Journal of Geotechnical Geoenvironmental Engineering. Vol. 134, p. 762-779.2008.

Storesund, Rune, "Characterization of consolidation settlement analysis uncertainties using probabilistic methods," Margins of Quality in Engineered Systems, University of California, Berkeley, 2006.

Cousins, Mary and Rune Storesund, "Post-Project Appraisal of Arroyo Viejo Creek Improvement, Oakland, California," December 1, 2005, Water Resources Archives, available from: http://repositories.cdlib.org/wrca/restoration/cousins

BOOKS

Storesund, Rune. "Introduction to Enterprise Risk Management in Socio-Technical Systems." In Development (2021-2022).

Storesund, Rune. "2017 Catastrophic Oroville Dam Spillway Disaster: Safety Culture Lessons To Be Learned." In Development (2021-2022).

Schulman, Paul and Rune Storesund. "Inter-Organization Safety Culture: The Concept and Its Creation." In Development (2021-2022).

Mitroff, Ian and Rune Storesund. "The Student's Guide to Crisis Management – Outsmarting Tomorrow's Crises Today." In Development (2021).

Mitroff, Ian and Rune Storesund. "Techlash: The Future of the Socially Responsible Tech Organization." Springer. Cham, Switzerland.

TECHNICAL REPORTS

Marvin R. Pyles, Rogers, David, Jonathan D. Bray, Arne Skaugset, Rune Storesund, Gunnar Schlieder. "Expert Report," Oso Landslide, March 2014. Superior Court of Washington for King County, Case No. 14-2-18401-8 SEA. June 30, 2016.

Rogers, David, Marvin R. Pyles, Jonathan D. Bray, Arne Skaugset, Rune Storesund, Gunnar Schlieder. "Interim Expert Report," Oso Landslide, March 2014. Superior Court of Washington for King County, Case No. 14-2-18401-8 SEA. January 22, 2016.

Rogers, David, Marvin R. Pyles, Jonathan D. Bray, Arne Skaugset, Rune Storesund. "Preliminary Expert Report," Oso Landslide, March 2014. Superior Court of Washington for King County, Case No. 14-2-18401-8 SEA. June 1, 2015.

Storesund, R., Dengler, L., Mahin, S., Collins, B. D., Hanshaw, M. F. Turner, M. F., and Welsh, K. "M 6.5 Earthquake Offshore Northern California January 9, 2010 *Field Reconnaissance Summary* " February 12, 2010. Available from: http://geerassociation.org/GEER_Post%20EQ%20Reports/NorthCA/M6-5_NorthernCalifornia_GEER_SummaryReport_Finalv2.pdf

Storesund, Rune, R.G. Bea, M. Bernhardt, J-L Briaud, D. Franken, A. Govindasamy, S-G Lim, D. Kim, M. Leclair, G. Hempen, N. Maerz, J.D. Rogers, C. Watkins. "Report to the National Science Foundation, 2008 Midwest Levee Performance Investigation, Summary of Initial Field Reconnaissance." March 16, 2009. Available from: http://www.worldcat.org/oclc/385265137

American Society of Civil Engineers (San Francisco Section), "Report Card 2005, Bay Area Infrastructure," available from: http://www.asce-sf.org/downloads/Report_Card.pdf

Seed, R.B., et al., "Preliminary Report on the Performance of the New Orleans Levee Systems in Hurricane Katrina on August 29, 2005," Report No. UCB/CITRIS-05/01, November 2, 2005, available from: http://www.ce.berkeley.edu/~new_orleans/report/PRELIM.pdf

Seed, R.B., et al., "Investigation of the Performance of the New Orleans Flood Protection Systems, in Hurricane Katrina on August 29, 2005, Final Report, July 31, 2006," University of California, Berkeley, available from: http://www.ce.berkeley.edu/~new_orleans/report

CONFERENCE PROCEEDINGS/PRESENTATIONS

Storesund, Rune, "Forensic Evaluation of Ground Vibrations & Noise in an Urban Drainage Project," National Academy of Forensic Engineers, Denver, Colorado. July 27, 2019.

Storesund, Rune, "Managing Complex Systems For Safety & Reliability Leveraging Human & Organizational Factors – Part II," Peder Sather Conference Discovery of Pragmatic Safety Management System Effectiveness Metrics, University of California, Berkeley, February 20, 2019.

Storesund, Rune, "Managing Complex Systems For Safety & Reliability Leveraging Human & Organizational Factors," University of Bergen, Norway, August 28, 2018.

Storesund, Rune, "FE Evaluation of Hillside Excavation For a Construction Contract Dispute," National Academy of Forensic Engineers, Phoenix, Arizona. January 13, 2018.

Storesund, Rune, "Forensic Engineer Expert Communications: Lessons Learned from the March 2014 Oso Landslide Litigation," National Academy of Forensic Engineers, Atlanta, Georgia, July 22, 2107.

Chin, Anne, O'Dowd, Alison P., Parker, Anna, Roberts-Niemann, Corine, and Storesund, Rune, "Initial Response of Step-Pool Streams to Wildfire," The Geological Society of America's 125th Anniversary Annual Meeting & Exposition, Denver, Colorado, Paper No. 13-72013, October 27-30 2013.

Bernhardt, M., Bea G.R., Briaud J.L., Franken D., Govindsamy A., Lim S.G.,Kim, D., Leclair, M., Hempen,G., Maerz, N.H., Rogers, J.D., Storesund, R., Watkins, C. (2009). "2008 Midwest Levee Performance Investigation: Summary of Erosion and Index Testing," Proceedings of 2009 NSF Engineering Research and Innovation Conference, Honolulu, Hawaii.

Bernhardt, M., Bea G.R., Briaud J.L., Franken D., Govindsamy A., Lim S.G.,Kim, D., Leclair, M., Hempen,G., Maerz, N.H., Rogers, J.D., Storesund, R., Watkins, C. (2009). "2008 Midwest Levee Failures: An Investigation," Proceedings of the ASCE Texas Section Meeting, Houston, TX.

Woo, Isa, Storesund, Rune, Takekawa, John Y., Gardiner, Rachel J. and Ehret, Steve, "Integrating Terrestrial LiDAR and Stereo Photogrammetry to Map the Tolay Lakebed in Northern San Francisco Bay," The Third Interagency Conference on Research in the Watersheds, Estes Park, Colorado, September 8-11, 2008.

Storesund, Rune, G. M. Kondolf, and Shannah Anderson. "Archiving of Restoration Project Information, An Invitation to Collaborate with the NRRSS Database." The California Society of Ecological Restoration (SERCAL). Santa Rosa, California. August 15, 2008.

Storesund, Rune, Kondolf, Mathias, Kern, Doug and Frey, Mark, "Application of Reliability in Design of River Ecosystem Restoration: a Case Study at the Tennessee Hollow Restoration Project on the Presidio in San Francisco, California," North American Benthological Society 55th Annual Meeting, Columbia, South Carolina, June 6, 2007.

Storesund, Rune, J. Toby Minear, G. M. Kondolf, "Evaluation of Ground-Based LiDAR for use in Fluvial Geomorphology and River Restoration," American Geophysical Union Fall 2006 Meeting, December 11-15, 2006.

Storesund, Rune, "Utilization of Terrestrial LiDAR in Reliability-Based Levee Operations and Maintenance," Delta Risk Conference, Sacramento, California, September 28-29, 2005.

Storesund, Rune, "Method, Trends, and Lessons Learned in Physical Channel Monitoring," 4th Biennial CALFED Science Conference 2006, Making Sense of Complexity: Science for a Changing Environment, October 23-25, 2006.

Anderson, Shannah, G. M. Kondolf, and Rune Storesund. "Lessons Learned from Urban Stream Restoration." The California Society of Ecological Restoration (SERCAL). Santa Rosa, California. August 15, 2008.

Briaud, J.-L., H.C. Chen, A.V. Govindasamy, and R. Storesund, "Erosion Tests on Samples From the New Orleans Levees," ASCE GEO-Denver, 2007.

Seed. R.B., et al., "Investigation of Levee Performance in Hurricane Katrina: The Inner Harbor Navigation Channel," ASCE GEO-Denver, 2007.

Seed, R.B., et al., "Investigation of Levee Performance in Hurricane Katrina: The New Orleans Drainage Canals," ASCE GEO-Denver, 2007.

Seed, R.B. et al., "Investigation of the Performance of the New Orleans Regional Flood Protection Systems During Hurricane Katrina: Lessons Learned," ASCE GEO-Denver, 2007.

Storesund, Rune, Jake Massey, Youngmin Kim. "Life Cycle Impacts for Concrete Retaining Walls vs. Bioengineered Slopes." In ASCE GeoCongress 2008: Geosustainability and Geohazard Mitigation, p. 875-882.

LECTURES AND NON-CONFERENCE PRESENTATIONS

"Risk and Crisis Management Bootcamp for Engineers, An Overview," American Society of Civil Engineers, San Francisco Section – Redwood Empire Branch, November 12, 2020.

Guest lecture: ENGI 4717 Applied Environmental Science and Engineering (2007), undergraduate core course, Department of Civil Engineering, Memorial University (Instructor: Dr. Bing Chen), Spring 2020

Keynote speech: PEOPLE Symposium on Persistent, Emerging and Oil PoLlution in Aquatic Environments (PEOPLE 2019), which will take place in St. John's, NL, Canada, on October 17-18, 2019

Organizing Committee member of PEOPLE Symposium on Persistent and Emerging Organic PoLlution in cold and coastal Environments (PEOPLE 2017), John's, NL, Canada, on October 16-17, 2017

"Use of Inquiry Systems to Overcome E3 Errors (Solving the Wrong Problem Precisely)," San Francisco Learning Lab, Division of Risk Management and Societal Safety, Lund University, Sweden. May 8, 2019.

"Managing Complex System For Safety & Reliability Leveraging Human & Organizational Factors – US Dams," May 11, 2018.

"Risk Assessment & Management – California Infrastructure," UC Center Sacramento, July 18, 2017.

"Hazards, Threats, and Risk, Oh My!" First Annual Workshop on Risk Assessment and Management, U.C. Berkeley CCRM. February 25 & 26, 2016.

"Reliability of Levee Systems in California, Sherman Island Case Study, Lessons Learned." U.C. Berkeley Levee Seminar. May 13, 2011.
"Surveying Creek and River Restoration." LA 222 – Hydrology for Planners. UC Berkeley. April 27, 2011.
"RESIN – Resilient and Sustainable Infrastructure Networks." Contra Costa Council. January 19, 2011.
"Restoration of Creeks and Rivers." UC Berkeley CE 24. March 31, 2010.
"Reliability-Based River Restoration." American Society of Civil Engineers, Water Resources Group. February 16, 2010.
"Reliability-Based River Restoration." American Society of Civil Engineers, San Jose Branch. February 9, 2010.
"Restoration of Creeks and Rivers." UC Berkeley CE 24. March 4, 2009.
"Tips & Tricks to be a Field Rockstar." LA 222 – Hydrology for Planners. UC Berkeley Department of Landscape Architecture. January 29, 2009.
"Midwest Levee Investigation." Center for Catastrophic Risk Management (CCRM). U.C. Berkeley. October 15, 2008.
"Lower Santa Ynez Bank Stabilization Project." California Department of Fish and Game. September 26, 2008.
"Overview of Terrestrial LiDAR." American Society of Civil Engineers, San Francisco Section Younger Member Forum. Oakland, California. August 14, 2008.
"An Overview of River Restoration Post Project Appraisals." Ecosystem Conservation Society – Japan. University of California, Berkeley. July 10, 2008.
"Composite Digital Terrain Models: Toward 4-D Channel Monitoring." San Francisco Estuary Institute (SFEI). April 23, 2008.
"Restoration of Creeks and Rivers." UC Berkeley CE 24. April 16, 2008.
"Overview of Terrestrial LiDAR." City of Emeryville. Emeryville, California. January 23, 2008.
"Restoration of Creeks and Rivers." UC Berkeley CE 24. October 24, 2007.
"Emerging Trends in Terrestrial LiDAR," Cal GIS conference, April 4, 2007. Panelist: Acquiring, Processing, and using LiDAR data.
"An Overview of Life-Cycle Reliability Based Design and Management Approaches to Urban Creek and River Restoration," Civil and Environmental Engineering Journal Club, University of California, Berkeley, November 2006.
"Methods, Trends, and Lessons Learned from Physical Channel Monitoring." CALFED Symposium. November 2006.
"Sustainability in Engineered Flood Control Projects," Landscape Architecture and Environmental Planning 227: River Restoration, University of California, Berkeley, November 2006.
"Tennesse Hollow in the Presidio: post-construction hydrologic response and performance," Third Annual California Water Symposium, University of California, Berkeley, May, 2006.
Cousins, Mary and Rune Storesund, "Post-Project Appraisal of Arroyo Viejo Creek Improvement, Oakland, California," Third Annual Berkeley River Restoration Symposium, University of California, Berkeley, December, 2005.

COURT-APPOINTED EXPERT WITNESS TESTIMONY (CIVIL ENGINEERING)

Civil District Court for the Parish of New Orleans, State of Louisiana. Sewell v. S&WB – Flight 2 Commercial. 2018
Civil District Court for the Parish of New Orleans, State of Louisiana. Sewell v. S&WB – Group B. 2018
Civil District Court for the Parish of New Orleans, State of Louisiana. Sewell v. S&WB – Group A. 2017
Superior Court of California, County of Napa. Hynes v. Menaged. 2017
Superior Court of California, County of San Joaquin. Vanni et al., v. Rindge Land Reclamation (Jones Tract Levee Failure). 2011.

PROFESSIONAL RESUME

Rune Storesund, D.Eng., P.E., G.E.
Consulting Engineer

EDUCATION:

D. Eng Civil Engineering, University of California, Berkeley, 2004-2009
(*Dissertation: Life-Cycle Reliability-Based River Restoration*)
Management of Technology Certificate Program, HAAS, UC Berkeley, 2007
M.S. Civil Engineering, University of California, Berkeley, 2002 (Geotechnical Engineering)
B.S. Civil Engineering, University of California, Berkeley, 2000
B.A. Anthropology, University of California, Santa Cruz, 2000

QUALIFICATIONS:

- California, Civil Engineer, RCE 64473
- California, Geotechnical Engineer, GE 2855
- Louisiana, Civil Engineer, RCE 35034
- Hawaii, Civil Engineer PE-15439
- Washington, Civil Engineer PE 52924
- Board Certified Diplomat, Forensic Engineering (NAFE)
- State of California Qualified Stormwater Practitioner/Designer (QSP/QSD)
- California Safety Assessment Program Disaster Service Worker
- NAUI Scuba Diver Openwater I (1994)

EXPERIENCE:

Dr. Storesund has over 20 years of planning, design, engineering, and construction experience and has worked on a variety of projects throughout California, the United States, and internationally. Dr. Storesund provides consulting services in all aspects of civil, geotechnical, water resources, ecological, restoration, and sustainability engineering projects. His expertise is on the application of reliability and risk-based approaches to engineering projects (with a specialization in environmental restoration and flood control projects) in order to effectively manage project uncertainties. Dr. Storesund has participated in all aspects of engineering projects; from preliminary reviews to detailed analyses to construction observations and post-project monitoring. He provides expert forensic engineering services for geotechnical and civil infrastructure systems. In addition to traditional engineering services, he provides consultations on field instrumentation and monitoring programs as well as Terrestrial LiDAR field survey services. His doctoral research was on life-cycle, reliability-based river restoration. Dr. Storesund serves as an on-call expert Geotechnical Engineer to the State of California's Department of Consumer Affairs for their annual examination.

Dr. Storesund is the Executive Director of UC Berkeley's Center for Catastrophic Risk Management (risk.berkeley.edu). The Center for Catastrophic Risk Management (CCRM) is a group of academic researchers and practitioners who recognize the need for interdisciplinary solutions to avoid and mitigate tragic events. This group of internationally recognized experts in the fields of engineering, social science, medicine, public health, public policy, and law was formed following the tragic consequences of Hurricane Katrina to formulate ways for researchers and experts to share their lifesaving knowledge and experience with industry and government. CCRM's international membership provides experience across cultures and industries that demonstrate widespread susceptibility to pervasive threats and the inadequacy of popular, checklist-based remedies that are unlikely to serve in the face of truly challenging problems.

Dr. Storesund is the founding member and President of SafeR^3, a California non-profit that specializes in risk and crisis management education and technology development that disseminates state-of-the-art and innovative enterprise risk management to state-of-the-practice via pragmatic tools and education that increase safety, resilience, and reliability as well as measurable risk-reduction.

Dr. Storesund is the CEO and founding member of NextGen Mapping, Inc., a software start-up company focused on leveraging big data associated with infrastructure systems to improve decision-making and connect decision-makers with real time (or near-real time) business intelligence models to enable informed and educated decisions.

Dr. Storesund is also the CEO and founding member of Storesund Construction Inc. (Lic No 1069275) a State of California Class A, B, & C-57 General Contractor specializing in mass grading, earthen reservoirs, water tanks, and water distribution and treatment systems.

PROJECTS: Projects Dr. Storesund has worked on are listed below:

Environmental Restoration

Louisiana Coastal Protection and Restoration (LACPR): Working with Environmental Defense, Dr. Storesund provided consultation services on proposed coastal restoration efforts in Louisiana, submitted by the United States Army Corps of Engineers (USACE). Dr. Storesund developed planning and design evaluation metrics by which to evaluate the adequacy of the proposed restoration alternatives. Additionally, Dr. Storesund is perfored a technical review of the risk-based design prepared by the USACE.

Arroyo de la Laguna Creek Bank Stabilization Project, Pleasanton, California: Storesund Consulting was the project geotechnical engineer for this bank stabilization project. Extreme precipitation events in 2017 resulted in catastrophic erosion and scour of the incised Arroyo de la Laguna creek and threatened residential structures along the bank. A habitat-friendly solution was designed and constructed that consisted of geotextile enclosed core embankment fill with a stepped coir log façade to facilitate revegetation. Natural, onsite materials were used in lieu of rock riprap trucked in from Vallejo.

Yellow Jacket Creek Fish Passage, Calistoga, California: This fish passage project improves a section of Yellow Jacket Creek to install a step-pool sequence to eliminate an existing concrete spillway that serves as a migratory barrier for salmonids. Dr. Storesund provided geotechnical recommendations in support of the restoration design.

Yosemite Slough Restoration: Dr. Storesund served as a project engineer, providing geotechnical recommendations during design. Project specifications were developed for this restoration project in San Francisco, California. The USACE SPECSINTACT program was used to develop the specifications.

Hamilton Wetland Restoration Project Shaping Contract, Novato, California: Dr. Storesund served as the geotechnical engineer of record for this earthwork project to shape dredge spoils into habitat features. Four areas (North Seasonal Wetland, Wildlife Corridor, Tidal Panne, and South Seasonal Wetland), each having different habitat requirements, were configured as part of the restoration project. A special low-permeability bottom was developed to minimize water infiltration and maximize salt retention in the seasonal tidal areas (habitat feature).

Suisuin Creek Watershed Instream Flow Enhancement Project: Dr. Storesund served as the project engineer to model in-reservoir inflows using EPA SWMM and reservoir temperatures using CE-QUAL-W2 (along with Dr. Scott Wells) in order to develop operational water release routines for the summer and fall so that downstream in-stream temperatures are beneficial for steelhead trout under dry, normal, and wet rainfall years.

Redwood Creek, Napa County, California: Dr. Storesund provided topographic as-built and photographic documentation for this in-stream habitat enhancement project. Boulder features were added to provide channel roughness and resting pools for migrating fish.

Upper Napa River Restoration Project, Napa County, California: Dr. Storesund served as the lead engineer providing civil, geotechnical, environmental, hydrological engineering and topographic mapping services for a four-mile stretch of the Napa River south of Calistoga, California. The project was sponsored by the California Land Stewardship Institute.

Sulphur Creek Monitoring, Hayward, California: Dr. Storesund is conducting annual geomorphic monitoring (for a total of 10 years) of this completed restoration project in Hayward, California. The project included slope stabilization and installation of habitat features (rock boulders). The monitoring includes surveys (cross-sectional, thalweg) and photo monitoring.

Kirby Canyon Landfill Mitigation, Santa Clara County, California: Dr. Storesund provided geotechnical engineering recommendations for this dam removal and creek restoration project. The site is located in a very steep canyon, with high gradients. In addition, the dam had been overtopped during previous storms, resulting in very deeply incised ravines forming (which needed to be backfilled).

Waldo Point Wetland Restoration, Marin County, California: This project is a wetland restoration project. Dr. Storesund provided topographic survey and piezometer monitoring services to establish connectivity parameters between San Francisco Bay and the proposed wetland mitigation site.

Huichica Creek Fish Passage: A fish-friendly culvert was designed as part of Caltran's Highway 36 widening project in Sonoma County, California. Dr. Storesund developed the conceptual and final designs, project specifications, and project cost estimate.

Great Valley Grasslands, Merced County, California: Dr. Storesund served as the project manager and project engineer for this floodplain reconnection project at the Great Valley Grasslands State Park. His evaluations consisted of a site reconnaissance, erosion/scour susceptibility screening, and hydraulic analysis of inundation through a series of existing culverts.

Pond 1 Restoration, Mountain View, California: Storesund Consulting performed a topographic survey of existing conditions to develop a base map for grading to alter onsite flood discharge to minimize inundation times (and prevent die-off of vegetation due to temporary storm water retainage). We developed grading plans, specifications, performed construction staking and performed an as-built survey using Terrestrial LiDAR methods.

ECCC Souzal, Antioch, California: Storesund Consulting performed a high-resolution RTK GPS survey of this wildlife area in order to generate a detailed topo to evaluate micro-watersheds for vernal pool development.

Hess Creek Restoration, Clayton, California: Storesund Consulting performed a high-resolution RTK GPS survey of this incised creek stretch to be restored. The survey results were integrated with available aerial LiDAR topography. We also provided geotechnical recommendations for the restoration plans.

Rancho San Vicente, New Almaden, California: Storesund Consulting provided geotechnical recommendations for this restoration project which involved the removal/stabilization of 16,000 CY of earthen fill dumped into a ravine on County Park Land. The recommendations involved environmental contamination, grading operations, temporary haul roads, slope stability, and earthwork.

Port of Richmond, Operable Unit 2: Dr. Storesund provided geotechnical design on this environmental remediation and restoration project within the Port of Richmond. The mitigation consisted of a subaqueous cap (comprised of Bay Mud) in the inlet, installation of rip-rap along the shoreline revetment zone, and installation of a concrete facing and asphalt concrete cap to isolate in place sediments.

Port of Oakland, Operable Unit 2: Dr. Storesund provided geotechnical design support services to Land Marine Geotechnics on this reclamation and restoration project within the Port of Oakland. Dredged spoils were used to abandon a deep-draft U.S. Navy pier at the Port of Oakland.

Storm Water Pollution Prevention Plans

Repetto Reservoir, San Gregorio, California: A SWPPP was prepared for this agricultural water reservoir enlargement project that increased capacity from 8.5 ac-ft to 19.5 ac-ft. Dr. Storesund served as both the stormwater designer and onsite practitioner.

Oakley Civic Center Frontage Improvements, State Route 4, Oakley, California: A SWPPP was prepared for this widening project in Oakley. The existing Main Street in the project limits has two westbound lanes and one lane eastbound. The project added pavement, roadway entries/exits, curb, gutter and sidewalks on the south side of Main Street, as well as street lights along both sides of Main Street.

Blue House Farms, San Gregorio, California: A SWPPP was prepared for this agricultural water reservoir enlargement project that increased capacity from 6 ac-ft to 30.5 ac-ft. Dr. Storesund served as both the stormwater designer and onsite practitioner.

Brentwood Boulevard Widening and Reconstruction From Woodfield Lane to Central Boulevard, Brentwood, California: A SWPPP was prepared for this project which widens the current Brentwood Boulevard (State Route 4) between Woodfield Lane and Central Boulevard from the existing geometry of a three-lane with two way left turn lanes to a four-lane roadway with a raised landscape median and turn pockets at intersections. Project demolition included removal of curb and gutter, sidewalk sections, damaged pavement sections, and removal of select trees.

Mainstreet Roadway Improvement Plans for Subdivision 8916, Oakley, California: A SWPPP was prepared for this roadway improvement project in Oakley, California. The project added pavement curb & gutter and sidewalk to the west side of the existing roadway in order to facilitate future addition of a second eastbound lane.

Sand Creek Road Intersection Improvement Project, Brentwood, California: A SWPPP was prepared for this project which expands an existing intersection and widens the roadway. The project added pavement, curb & gutter, and sidewalks.

Sausalito Yacht Harbor, Sausalito, California: Dr. Storesund developed a design for treatment of storm water runoff in the large parking lot adjacent to the Sausalito Yacht Harbor as part of a bulkhead wall replacement project. The design involved the installation of a permeable rock infiltration zone under a walkway area. This infiltration area was designed to treat storm water runoff before it enters Richardson Bay.

Flood Control

California Rural Levee Repair Criteria Committee: This advisory committee was charged with developing rural levee repair and improvement criteria to be applied for planned or emergency work. The group worked in conjunction with DWR, interested stakeholders, and USACE. Dr. Storesund provided engineering (seismic, geotechnical marine, ecological, water resources) and risk-based decision making input to this group. This committee was active between 2012 and 2014.

USACE West Sacramento Flood Control Project, West Sacramento, California: Dr. Storesund served as a field engineer responsible for field construction quality control program, which consisted of sand cone density testing, nuclear gauge density testing, associated geotechnical laboratory testing, and issuing a final services during construction report.

Warm Springs Dam Control Structure Study, Sonoma County, California: Dr. Storesund served as the project manager and project engineer for this crack evaluation study for the San Francisco US Army Corps of Engineers. The study was performed in conjunction with PB. The vertical control structure for Warm Springs Dam suffered from water infiltration due to cracking of the concrete control structure. A LiDAR imaging and visual observation mapping was conducted of the cracks. Repair recommendations and cost estimate were provided to the US Army Corps of Engineers.

Las Gallinas Coastal Inundation Study, Marin County, California: Dr. Storesund served as a project engineer for this study (for the San Francisco US Army Corps of Engineers) that evaluated overtopping conditions during storm events for an existing flood protection system. Dr. Storesund developed a GIS terrain and inundation maps based on overtopping analyses.

Upper Penitencia Creek, Subsurface Geotechnical Exploration, Santa Clara County, California: Dr. Storesund served as the project engineer for this United States Corps of Engineers project which consists of on-land, subsurface geotechnical exploration along a portion of Upper Penitencia Creek. The requested services include drilling, sampling, field classification, laboratory testing, and Unified Soil Classification System (USCS) for soil borings at select locations along the creek alignment. The purpose of the soil borings was to provide subsurface data for the preliminary design of flood control structures, such as levees, floodwalls, culverts, and weirs along Upper Penitencia Creek. Dr. Storesund coordinated and managed Fugro's field operation exploration program that consisted of 22 soil test borings. Following the field exploration, Dr. Storesund managed the QA/QC review of all field and laboratory data. Dr. Storesund also managed the data report preparation.

Geotechnical Study Northern Borrow Area, Bulge And Pacheco Pond Levees, Hamilton Wetlands Restoration Area, Novato, California: Dr. Storesund served as the project engineer for this project which consisted of a geotechnical study for the Bulge and Pacheco Levees located in the Hamilton Wetlands Restoration Area. The project site is situated at the former Hamilton Army Air Field in Novato, California. The purpose of the geotechnical field exploration and laboratory testing program was to obtain information on subsurface conditions in the Northern Borrow Area in order to estimate the amount and nature of potential borrow material. The scope of services performed included:

- Conducting a field exploration program consisting of 18 test pits to determine the subsurface profile in the Northern Borrow Area;
- Conducting a laboratory testing program to obtain soil properties of the samples collected during our field exploration; and
- Preparing this geotechnical report presenting the results of our geotechnical field exploration, laboratory testing program, and a discussion of the exploration results.
- Specified development / review

USACE San Lorenzo Flood Control, Santa Cruz, California: Dr. Storesund served as a field engineer responsible for field density testing, performing associated geotechnical laboratory testing, and issuing a final services during construction report for this levee project in Santa Cruz.

USACE Napa River Flood Protection, Napa, California: Dr. Storesund served as a field engineer responsible for field density testing, performing associated geotechnical laboratory testing, and issuing a final services during construction report for this levee project in Napa.

Codornices Creek Restoration Project, Between Fifth and Eighth Streets, Albany and Berkeley, California: Dr. Storesund served as the project engineer for this geotechnical study. The purpose of this project is to restore the existing Codornices Creek, located between the City of Albany and the City of Berkeley, to a more natural setting using bioengineering and biotechnical methods. Dr. Storesund was responsible for the geotechnical field exploration and laboratory-testing program. The scope of our services included: Compiling and reviewing available geotechnical and geologic data; conducting a field exploration and laboratory-testing program; evaluation of slope stability and erosion susceptibility; development of embankment fill recommendations and general construction considerations; and preparing a final geotechnical report that included the results of our geotechnical field exploration and laboratory testing program, discussion of geotechnical issues, and geotechnical recommendations

Water Storage Reservoirs

Napa, Sonoma, and Lake Counties, California: Provided engineering design recommendations and construction observations services for water storage reservoirs for various agricultural clients. Reservoirs are off-stream, agricultural purpose reservoirs or are on-stream reservoirs with embankment heights less than 25 feet and store less than 50 acre-feet. Thus, the reservoirs are not within the jurisdiction of the California Department of Dam Safety (DSOD). Projects include construction of earth embankments and placement of either low permeability compacted soil liners or installation of geosynthetic liner systems.

- **Brooks Reservoir, Napa County, California:** 2.5 acre-foot, off-stream water storage reservoir formed by constructing three earthen embankments and lined with a geosynthetic liner.
- **Platt Reservoir, Sonoma County, California:** An off-stream reservoir formed by constructing a compacted earthen embankment with on-site soils. The reservoir was lined with a geosynthetic liner. The project included installation of an underdrain system to preclude the "floating" of the synthetic liner if the reservoir is drained during periods of high groundwater as well as a cut slope drain to intercept hillside groundwater flows. Dr. Storesund was also responsible for issuing a final services during construction report for the project.
- **Mondavi Dutra Dairy Reservoir, Napa County, California:** Dr. Storesund served as a field engineer responsible for embankment keyway inspections, field density testing, and concrete placement quality control during the enlargement of this reservoir in Napa County. Dr. Storesund was also responsible for issuing a final geotechnical services during construction report for the project.
- **Amber Knolls Reservoir, Lake County, California:** Dr. Storesund served as a field engineer responsible for embankment keyway inspections, field density testing, and concrete placement quality control during the construction of this reservoir in Lake County. Dr. Storesund was also responsible for issuing a final geotechnical services during construction report for the project.
- **Red Hills Reservoir, Lake County, California:** Dr. Storesund served as a field engineer responsible for embankment keyway inspections, field density testing, and concrete placement quality control during the construction of this reservoir in Lake County. Dr. Storesund was also responsible for issuing a final geotechnical services during construction report for the project.
- **Chimney Rock Vineyard, Napa County, California:** Dr. Storesund served as a field engineer responsible for embankment keyway inspections and field density testing during the construction of this reservoir in Napa County.
- **Hershey Vineyard Reservoir, Sonoma County, California:** Dr. Storesund served as a staff engineer responsible for generating design recommentions and issuing of a final geotechnical design report for this reservoir project in Sonoma County.
- **BV Reservoir No. 10 Rehabilitiation, St. Helena, California:** Dr. Storesund served as a field engineer responsible for the execution of the field investigation program and issuance of a final geotechnical design report for this reservoir rehabilitation project in St. Helena.

Mazzera Agricultural Reservoir Project, Healdsburg, California: Dr. Storesund served as the project manager and project engineer for this off-stream reservoir storage project, providing all aspects of engineering planning (permit assistance, conceptual layouts), design (site geotechnical exploration and survey, analyses, development of plans, specifications, and estimates), and construction oversight during construction. This project is part of the Grape Creek Streamflow Stewardship Project (GCSSP); a cooperative project designed to help landowners manage water resources in a manner that balances water use with habitat and minimum required in-stream flows for listed coho salmon and steelhead trout. An existing flashboard dam and containment berm was replaced with a new reservoir adjacent to the creek to allow passage of river flows while providing the farmer with an agricultural water supply.

Repetto Farms Reservoir, San Gregorio, California: Dr. Storesund served as the project engineer and project manager for this off-stream reservoir storage project, providing all aspects of engineering planning (permit assistance, conceptual layouts), design (site geotechnical exploration and survey, analyses, development of plans, specifications, and estimates). This agricultural water reservoir enlargement project increased capacity from 8.5 ac-ft to 19.5 ac-ft. Storesund Engineering LLC was the General Contractor.

Moty Property Reservoir, San Gregorio, California: Dr. Storesund served as the project engineer and project manager for this off-stream reservoir storage project, providing all aspects of engineering planning (permit assistance, conceptual layouts), design (site geotechnical exploration and survey, analyses, development of plans, specifications, and estimates). This agricultural water reservoir project created a reservoir with a design capacity of approximately 19.5 ac-ft.

Muzzi Property Reservoir, San Gregorio, California: Dr. Storesund served as the project engineer and project manager for this off-stream reservoir storage project, providing all aspects of engineering planning (permit assistance, conceptual layouts), design (site geotechnical exploration and survey, analyses, development of plans, specifications, and estimates), and construction oversight. This agricultural water reservoir project created a reservoir with a design capacity of approximately 19.5 ac-ft.

Oku Property Reservoir, San Gregorio, California: Dr. Storesund served as the project engineer and project manager for this off-stream reservoir storage project, providing all aspects of engineering planning (permit assistance, conceptual layouts), design (site geotechnical exploration and survey, analyses, development of plans, specifications, and estimates). This project included a rain harvesting system for approximately 10 acres of greenhouse roof, a pumping system to discharge to a water reservoir, and rehabilitation of an existing ~25 ac-ft water reservoir.

Water Systems

Loma Mar Mutual Water Company, Loma Mar, California: Dr. Storesund served as the project engineer and project manager for the re-design of the water distribution system for the Loma Mar Mutual Water Company, providing all aspects of engineering planning (permit assistance, conceptual layouts), design (site exploration and survey, analyses, development of plans, specifications, and estimates).

Bricarello Residence, Gilroy, California: Dr. Storesund served as the project engineer and project manager for this off-stream water storage project, providing all aspects of engineering planning (permit assistance, conceptual layouts), design (site geotechnical exploration and survey, analyses, development of plans, specifications, and estimates). The project included a reinforced concrete pad grading and preparation for 30,000 gallons of raw water storage, a water polishing system, a water treatment system, and water distribution system. This project was part of the Little Arthur Creek Streamflow Stewardship Project (LACSSP) is a cooperative project designed to help landowners develop water supply security in a manner that improves in stream flows and habitat for listed steelhead trout. Storesund Engineering LLC was the General Contractor.

Gifford Residence, Gilroy, California: Dr. Storesund served as the project engineer and project manager for this off-stream water storage project, providing all aspects of engineering planning (permit assistance, conceptual layouts), design (site geotechnical exploration and survey, analyses, development of plans, specifications, and estimates). The project included a creek diversion, pad grading and preparation for 40,000 gallons of raw water storage, a water polishing system, a water treatment system, and water distribution system. This project was part of the Little Arthur Creek Streamflow Stewardship Project (LACSSP) is a cooperative project designed to help landowners develop water supply security in a manner that improves in stream flows and habitat for listed steelhead trout.

Ford Residence, Gilroy, California: Dr. Storesund served as the project engineer and project manager for this feasibility-level off-stream water storage project This project was part of the Little Arthur Creek Streamflow Stewardship Project (LACSSP) is a cooperative project designed to help landowners develop water supply security in a manner that improves in stream flows and habitat for listed steelhead trout.

Bates Residence, Gilroy, California: Dr. Storesund served as the project engineer and project manager for this off-stream water storage project, providing all aspects of engineering planning (permit assistance, conceptual layouts), design (site geotechnical exploration and survey, analyses, development of plans, specifications, and estimates). The project consisted of demolition of an existing 30,000 gal reinforced concrete tank with a new 50,000 corrugated steel agricultural water tank. This project was part of the Little Arthur Creek Streamflow Stewardship Project (LACSSP) is a cooperative project designed to help landowners develop water supply security in a manner that improves in stream flows and habitat for listed steelhead trout. Storesund Engineering LLC was the General Contractor.

Hepner Residence, Gilroy, California: Dr. Storesund served as the project engineer and project manager for this off-stream water storage project, providing all aspects of engineering planning (permit assistance, conceptual layouts), design (site geotechnical exploration and survey, analyses, development of plans, specifications, and estimates). The project included a creek diversion, reinforced concrete pad grading and preparation for 40,000 gallons of raw water storage, a water polishing system, a water treatment system, and water distribution system. This project was part of the Little Arthur Creek Streamflow Stewardship Project (LACSSP) is a cooperative project designed to help landowners develop water supply security in a manner that improves in stream flows and habitat for listed steelhead trout. Storesund Engineering LLC was the General Contractor.

Kapp Residence, Gilroy, California: Dr. Storesund served as the project engineer and project manager for this off-stream water storage project, providing all aspects of engineering planning (permit assistance, conceptual layouts), design (site geotechnical exploration and survey, analyses, development of plans, specifications, and estimates). The project included a reinforced concrete pad grading and preparation for 40,000 gallons of raw water storage, a water polishing system, a water treatment system, and water distribution system. This project was part of the Little Arthur Creek Streamflow Stewardship Project (LACSSP) is a cooperative project designed to help landowners develop water supply security in a manner that improves in stream flows and habitat for listed steelhead trout. Storesund Engineering LLC was the General Contractor.

Starkovich Residence, Gilroy, California: Dr. Storesund served as the project engineer and project manager for this off-stream water storage project, providing all aspects of engineering planning (permit assistance, conceptual layouts), design (site geotechnical exploration and survey, analyses, development of plans, specifications, and estimates). The project included a reinforced concrete pad grading and preparation for 100,000 gallons of raw water storage, a water polishing system, a water treatment system, and water distribution system. This project was part of the Little Arthur Creek Streamflow Stewardship Project (LACSSP) is a cooperative project designed to help landowners develop water supply security in a manner that improves in stream flows and habitat for listed steelhead trout. Storesund Engineering LLC was the General Contractor.

Memorial Park, San Mateo County, California: Dr. Storesund served as the project engineer and project manager for this off-stream water storage project and water distribution line upgrades for San Mateo County Parks, providing all aspects of engineering planning (permit assistance, conceptual layouts), design (site geotechnical exploration and survey, analyses, development of plans, specifications, and estimates). The project included a water polishing treatment pilot study to examine efficacy of no treatment; ozone treatment; and slow sand filter treatment. Target storage capacity is on the order of 1.25 million gallons. This project was part of the Pescadero Creek Streamflow Stewardship Project is a cooperative project designed to help landowners develop water supply security in a manner that improves in stream flows and habitat for listed steelhead trout.

Portola Redwoods State Park, San Mateo County, California: Dr. Storesund served as the project engineer and project manager for this off-stream water storage project for the California State Parks, providing all aspects of engineering planning (permit assistance, conceptual layouts), design (site geotechnical exploration and survey, analyses, development of plans, specifications, and estimates). Target storage capacity is on the order of 750,000 gallons. This project was part of the Pescadero Creek Streamflow Stewardship Project is a cooperative project designed to help landowners develop water supply security in a manner that improves in stream flows and habitat for listed steelhead trout

Pescadero Creek Streamflow Stewardship, San Mateo County, California: Dr. Storesund served as the project manager and project engineer for this off-stream reservoir storage project, providing all aspects of engineering planning (permit assistance, conceptual layouts), design (site geotechnical exploration and survey, analyses, development of plans, specifications, and estimates), and construction oversight during construction. The Pescadero Creek Streamflow Stewardship Project is a cooperative project designed to help landowners develop water supply security in a manner that improves in stream flows and habitat.

Town of Whitethorn Auxiliary Water Storage System, Whitethorn, California: Dr. Storesund served as the principal engineer on this conservation project performed in collaboration with Trout Unlimited and Sanctuary Forest. The project entailed installation of an additional 100,000 gallons of water storage and new distribution lines as well as a slow sand polishing system. Dr. Storesund performed the permitting, planning, engineering, construction bid documentation, and review services.

Whitethorn Elementary School Auxiliary Water Storage System, Whitethorn, California: Dr. Storesund served as the principal engineer on this conservation project performed in collaboration with Trout Unlimited and Sanctuary Forest. The project entailed installation of sixteen 5,000 gallon water tanks so that the school could divert water during wet months. Dr. Storesund performed the permitting, planning, engineering, construction bid documentation, and review services.

Girard Vineyard, 50k Gallon Water Tank, Napa County, California: Dr. Storesund served as a field engineer during the geotechnical exploration of this project. Two tank sites were evaluated during the field operations by excavating test pits. Site-specific foundation design recommendations were generated.

Residential

MLK Plaza Homes, Oakland, California: Dr. Storesund provided field density testing services for this low income housing project in Oakland. The project consisted of constructing thirteen new two-story residential structures at the site as well as associated improvements.

Standard Pacific Homes' Dublin Ranch, Dublin, California: Dr. Storesund served as a field engineer for this residential development in Dublin, observing mass grading operations, performed field density tests on housing pads, roadways, utility trenches, special inspections on rebar placement, concrete placement, post-tensioning, and performed related geotechnical laboratory testing. Dr. Storesund was also responsible for inspection and evaluation of erosion control systems in place during mass grading operations.

Palomares Hills, San Anselmo, California: Dr. Storesund served as a field engineer providing construction observations and field density testing during construction of retaining walls for this residential development.

Lund Ranch Creek, Pleasanton, California: Dr. Storesund provided construction observation services during a creek restoration project located within the Lund Ranch Creek residential development in Pleasanton. The restoration project involved bank erosion mitigation through placement of rock rip rap.

University Avenue Housing, Berkeley, California: Dr. Storesund served as a field and project engineer for this multi-unit residential housing project. An existing Salvation Army structure and parking lot were demolished and replaced with the new housing structure. Dr. Storesund performed the field exploration, engineering analyses, foundation recommendations, and prepared the final geotechnical design report.

The Estates at Happy Valley, Sun City, Arizona: Dr. Storesund served as a field engineer responsible for the execution of a field investigation program, which involved hollow stem auger drilling and geotechnical sampling for this mass grading residential development project in Sun City.

Educational

Children's Hospital Oakland Upgrade, Oakland, California: Dr. Storesund served as a staff engineering providing pipeline thrust block design recommendations for this facility upgrade project in Oakland.

Bessie Carmichael School, San Francisco, California: Dr. Storesund served as a staff engineer providing drilled pier design recommendations for this new school situated between the existing Saint Michael Ukrainian Orthodox Church and the Vineyard Christian Fellowship Church in San Francisco. It is three-story structure with a total footprint area of approximately 24,000 square feet. The facility features a single-story gymnasium and multi-purpose room with an elevated roof, a central courtyard area, and an asphalt-paved playground adjacent to the school building.

Blue Oaks School, Napa, California: Dr. Storesund served as a field engineer for this school renovation project in Napa. The field services consisted of field density testing on pavement subgrades and base rock.

Vista College Facility, Berkeley, California: Dr. Storesund served as a field engineer responsible for logging test pits to identify the foundations for existing structures surrounding the project site. The facility upgrade consisted of a new six to eight-story building for Vista College on the south side of Center Street, between Shattuck Avenue and Milvia Street in Berkeley. Excavations on the order of 15 to 20 feet were required to construct the basement level. The new foundations consisted of 36-inch diameter drilled piers with lengths from 50 to 70 feet.

New Alameda Elementary School, Alameda, California: Dr. Storesund served field as a field engineer responsible for the execution of the field exploration for this project. The new school will consist of classroom buildings and multi-use buildings. The scope of work for this investigation included a site reconnaissance by a State of California Certified Engineering Geologist, subsurface exploration utilizing both exploratory borings and Cone Penetration Testing, laboratory testing, engineering analyses of the field and laboratory data, and preparation of this report. The data obtained and the analyses performed were for the purpose of providing design and construction criteria for site earthwork, building foundations, slab-on-grade floors, retaining walls and pavements.

Ocean Branch Library, San Francisco, California: Dr. Storesund served as a staff engineer responsible for generating foundation recommendations for this new library structure in San Francisco.

Hospitals

Marin General Hospital, Greenbrae, California: Dr. Storesund served as the project manager and engineer for foundation design for a new at-grade one-story West Wing structure (about 4,500 square feet) that will be added onto the west side of the 1986 Hospital Structure. Additional miscellaneous site improvements to the West Wing structure included a new approximately 500-foot long retaining wall south of the proposed Patient Tower and revised entry and parking. The construction of the retaining wall will required excavations on the order of 35 feet into an undeveloped hillside along the southern boundary of the hospital property. The new entry circle was situated north of the proposed West Wing and the planned revised parking will be situated along the west side of the hospital property along Bon Air Road. Site grades will be raised up to four feet using lightweight fill to create the new circle and parking areas. The project was subject to OSPHD review.

Good Samaritan Hopsital, San Jose, California: Dr. Storesund served as the project manager and engineer for foundation design associated with a new four story elevator structure, emergency department walk-in/drop off area, and chiller structure. The scope of work included: . Review of existing information for the site and vicinity, including previous work and available geologic maps; Field exploration consisting of five (5) exploratory borings and a percolation test to supplement the available information on subsurface conditions at the site; Site reconnaissance by an Engineering Geologist to assess possible geological and seismic hazards; Laboratory testing program to characterize the engineering properties and corrosion potential of soils encountered during our field exploration; Engineering analyses to evaluate geologic hazards, and make recommendations for site earthwork, and building foundations; and Preparation of a report presenting the results of our geologic, seismic, and geotechnical studies, and recommendations for design and construction of the proposed project.

Commercial

Clear Channel Outdoor, Oakland, California: Dr. Storesund served as a staff engineer responsible for providing drilled pier design recommendations for this outdoor billboard structure. The proposed billboard structure was supported by four 24-inch diameter, 3/8-inch thick hollow steel pipe columns.

Metcalf Substation Storage Bank, Santa Clara County, California: Storesund Consulting provided initial site layout and configuration plans for a solar energy development project. The site evaluation included general grading and drainage recommendations.

Hollister Storage Bank, Hollister, California: Storesund Consulting provided initial site layout and configuration plans for a solar energy development project. The site evaluation included general grading and drainage recommendations.

BC Fisheries, Brookings, Oregon: Dr. Storesund provided geotechnical consultations for deep foundation for a new storage facility.

JB Radiator Complex, Sacramento, California: Dr. Storesund provided geotechnical recommendations for foundation grading for a new storage tank at a site with expansive soils.

Linde Processing Facility, Richmond, California: Dr. Storesund performed a field exploration program (CPT) to characterize onsite soil conditions and provided foundation design recommendations for new infrastructure developments at the property.

Moraga Country Club Landslide Mitigation, Moraga, California: Dr. Storesund served as a field engineer for three landslide mitigation projects at the Moraga Country Club. Dr. Storesund provided field density testing services and general construction observations. He was responsible for summarizing the field data and issuing a construction report.

Bayer Building 55, Berkeley, California: Dr. Storesund served as a field engineer responsible for field density testing services during construction for this new commercial facility in Berkeley.

Tionesta Compressor Pad, Tionesta, California: Dr. Storesund provided geotechnical recommendations for a drilled pier foundation design for a new storage tank at a site with undocumented fills overlying basalt bedrock.

San Jose Digesters, San Jose, California: Dr. Storesund served as the geotechnincal project manager and project engineer for upgrades to existing onsite digesters as well as new improvements consisting of electrical buildings, sludge equalization tanks, screening facilities, odor control and polymer tanks, and an elevated pipe rack system. The scope of services included: Compiling and reviewing available geotechnical and geologic data that is contained in our files and is pertinent to the project vicinity; Obtaining required permits and conducting a field exploration program (soil borings and CPT probes) to supplement the available information on subsurface conditions; Perform geotechnical laboratory testing on select samples for classification, index, and strength testing; Evaluation of select samples (2) for corrosion potential by a corrosion engineer to buried piping and reinforced concrete structures; Discussion of site geology, seismicity, and listing of seismic design parameters in accordance with the 2013 California Building Code; Evaluation of liquefaction potential and mitigation strategies (as necessary); Development of foundation design recommendations, including shallow foundation bearing capacities, passive resistance, coefficient of friction, deep foundation capacities, lateral soil pressures, and probable total and differential settlements; and Preparing this geotechnical report presenting the results of our geotechnical field exploration, discussion of geotechnical issues, and geotechnical recommendations.

West County Wastewater District Recycled Water Rehabilitation, Richmond, California: Dr. Storesund served as the geotechnincal project manager and project engineer for (a) a new aeration basin, storage, and a flow splitter, (b) a new WCWD site electrical building, and (c) miscellaneous mechanical improvements throughout the WCWD facility. The scope of work included: Review of existing data, including: published and unpublished geotechnical and geologic reports, including work performed by Fugro; and available foundation plans for existing structures; Perform four (4) Cone Penetration Tests (CPTs) to a depth of 100 feet to aid in characterizing in-situ soil conditions; Incorporation of applicable previous borings, CPTs and laboratory testing program results to help characterize the engineering properties, strength, compressibility, and corrosion potential of the onsite soils; Geologic and seismic hazard evaluation, including site geology and evaluation of seismicity, ground shaking, liquefaction potential, and associated settlement; Engineering analysis and recommendations of earthwork and foundations; and Preparing a geotechnical study report presenting the results of our data review, past geotechnical field exploration programs, discussion of geotechnical issues, and geotechnical recommendations for the proposed improvements.

Moss Landing Powerplant, Moss Landing, California: Dr. Storesund served as a field engineer for this power plant upgrade project in Moss Landing. Dr. Storesund provided construction observations auger cast pile installation for the main generating structure and piezometer monitoring during the construction and dewatering of the water cooling intake structure.

Coliseum Lexus Dealership, Oakland, California: Dr. Storesund served as a staff engineer responsible for generating foundation design recommendations and issuing the final geotechnical report for this dealership in Oakland.

Infiniti of Oakland Dealership, Oakland, California: Dr. Storesund served as a field engineer responsible for the implementation and execution of the field investigation program for this project which consisted of advancing three cone penetration tests (CPTs). In addition, he was also responsible for generating foundation design recommendations and issuing a final geotechnical design report.

Sho*Ka*Wah Casino Bridge, Hopland, California: Dr. Storesund served as a field engineer for this bridge and parking lot and suspension bridge project in Hopland. Dr. Storesund provided concrete sampling, keyway inspection, and field density testing services during construction.

WPCP Former Polishing Pond Equipment Project, San Leandro, California: Dr. served as the project manager and geotechnical project engineer for this project to place fill in a former polishing pond with onsite soils that will be stabilized ("stabilized fill") to create an equipment storage area. The stabilized fill consisted of approximately 16,000 cubic yards of soil stockpiled at the WPCP drying bed area. These fills were generated from the plant expansion construction. Chemical testing results indicated that the soil contains elevated concentration of lead, hydrocarbons, polychlorinated biphenyls (PCBs), and chlorinated pesticides. Scope of work included: Review of available existing geotechnical data at the site; Geotechnical exploration to evaluate subsurface conditions of the berms and pond bottom as well as the proposed fill material; Evaluate geotechnical considerations for placement of fill within the former polishing pond; Perform geotechnical feasibility evaluations of fill placement with respect to slope stability, settlements, and screening for lateral spreading potential during a seismic event; and Preparing a geotechnical report summarizing our findings.

Anthropologie – Berkeley, Berkeley, California: Dr. Storesund served as a field engineer responsible for executing the field exploration program for this structural upgrade project in Berkeley. Dr. Storesund was also responsible for the issuing of a final geotechnical design report

2150 Shattuck, Berkeley, California: Dr. Storesund served as a field engineer for this seismic retrofit project in Berkeley. Dr. Storesund was responsible for the monitoring of micropile installation and load testing. He was also responsible for quality control of the injected micropile grout.

Chino Bandito, Chandler, Arizona: Dr. Storesund served as a field engineer responsible for the execution of the field investigation program, which involved hollow stem auger drilling and geotechnical sampling for this 11,500 square foot commercial development project in Chandler.

150 Powell Street, San Francisco, California: Dr. Storesund served as the project manager and project engineer for this structural renovation project near Union Square. The historic building required the façade structure to be saved and incorporated into the new structure. Dr. Storesund developed and implemented an exploration program that involved test pits to expose and evaluate the condition of spread footings. Foundation design services were also provided for temporary construction features (tieback walls, support frame for façade) and permanent features (foundations) as well as support and observation services during construction.

390 Fremont Street, San Francisco, California: Dr. Storesund provided geotechnical engineering support to a property owner adjacent to a high-rise construction project that involved installation of a shoring system, excavation to a depth of 70 ft, excavation of soil and bedrock, and development and evaluation of a monitoring program during the excavation activities.

Waterfront and Offshore Facilities

California Tsunami Hazard Policy Committee: The California Tsunami Policy Working Group (CTPWG) is a voluntary advisory body operating under the California Natural Resources Agency (CNRA), Department of Conservation, and is composed of experts in earthquakes, tsunamis, flooding, structural and coastal engineering and natural hazard policy from government, industry, and non-profit natural hazard risk-reduction organizations. The working group serves a dual purpose as an advisor to State programs addressing tsunami hazards and as a consumer of insights from the SAFRR Tsunami Scenario project, raising awareness and facilitating transfer of policy concepts to other coastal states in the nation. CTPWG's role is to identify, evaluate and make recommendations to resolve issues that are preventing full and effective implementation of tsunami hazard mitigation and risk reduction throughout California's coastal communities. Dr. Storesund provided engineering (seismic, geotechnical marine, ecological, water resources) and risk-based decision making input to this group. This committee was active between 2011 and 2013.

Seawall Earthquake Safety Program, City and County of San Francisco: Storesund Consulting provided support services for the field exploration program for evaluation of the existing seawall in San Francisco. The field exploration program included mud rotary borings, Cone Penetration Tests, and sonic borings.

Emeryville Shoreline Protection Project, Emeryville, California: Dr. Storesund was a project engineer overseeing the construction of this shoreline improvement project. Site grades were raised 2-4 feet above existing grade and an enlarged shoreline breakwater slope was constructed.

Alcatraz Hydrodynamic Evaluation, City and County of San Francisco, California: Dr. Storesund was the project manager and project engineer for this coastal hazard screening evaluation at Alcatraz. The purpose of the screening was to inform long-range planning activities, accounting for shoreline erosion and sea level rise. The recommendations were provided to the National Park Service, in association with Kleinfelder.

Emeryville Marina Breakwater, Emeryville, California: Dr. Storesund was a project engineer responsible for the planning and execution of a field exploration and geotechnical laboratory testing program for this breakwater and pier project in Emeryville. Dr. Storesund also completed the geotechnical design recommendations and issued the design report.

Nelson's Marine Shoreline Stabilization, Alameda, California: Dr. Storesund served as the project manager and project engineer for this shoreline stabilization and remediation project at an abandoned boat yard within the Oakland Estuary. The project required an alternatives analysis (approach and cost estimate), decision matrix, development of remediation plans, specifications, and estimates. Field efforts included site surveys (RTK GPS) and geotechnical exploration.

Seadrift Shoreline Study, Stinson Beach, California: Dr. Storesund served as a project engineer and performed a site characterization study (based on historical topographic maps and aerial photographs), conducted hydrodynamic characterization, and aided with the design of the extension of an existing sheet pile bulkhead system along Bolinas Lagoon.

Loch Lomond Breakwater Improvement Project, San Rafael, California: Dr. Storesund was the project manager and a project engineer for the improvement of an existing 1,500 foot long rip rap breakwater structure. He performed a hydrodynamic evaluation during the planning phase to establish design criteria, managed the project (preparation of project plans, specifications, and estimates), and provided civil and geotechnical engineering expertise.

Harbor Point Shoreline Stabilization Project, Tiburon, California: Dr. Storesund served as a project engineer and performed a site characterization study (based on historical topographic maps and aerial photographs), conducted hydrodynamic characterization, and aided with the design of a shoreline stabilization solution.

Martin Luther King Jr. Drive Shoreline Study, Bay farm Island, California: Dr. Storesund served as the project manager and project engineer for this Bay Trail feasibility study for the East Bay Regional Park District (teamed with Creegan D'Angelo Engineers). Dr. Storesund prepared a screening-level coastal engineering guidance document and technical review of alternative plan elements.

Richmond Marina Breakwater Improvements, Richmond, California: Dr. Storesund served as a support staff engineer for this breakwater improvement project in Richmond. The project entailed wave and tide surveys, wind pattern evaluations, and preliminary foundation recommendations to upgrade an existing breakwater structure.

Third Street Boat Ramp, Lakeport, California: Dr. Storesund was a staff engineer responsible for organizing and performing the geotechnical exploration for this public boat ramp improvement project in Lakeport.

Dow Chemical Wharf, Pittsburg, California: Dr. Storesund was the project manager and a project engineer for the evaluation of an existing wharf to evaluate its ability to accommodate larger supply ships. After the initial review, Dr. Storesund was responsible for the development of alternatives, preparation of project permits, design of a new mooring system (including specifications and cost estimate), and construction observations and load testing.

Alviso Marina County Park, Alviso, California: Dr. Storesund served as a field engineer responsible for the implementation of Fugro's geotechnical exploration for the Alviso Marina County Park, Phase 1 Master Plan Implementation Project in Alviso. The geotechnical exploration consisted of two test borings, two Cone Penetration Tests (CPTs). Fugro evaluated the geotechnical conditions for the design and construction of the new parking area, a planted mound area (which includes the placement and compaction of up to 5 feet of engineered fill), and a 24-inch high by 18-inch wide flood control wall.

Brooklyn Basin Dredging Study, Oakland, California: Dr. Storesund served as the project manager for this maintenance dredging study commissioned by the San Francisco US Army Corps of Engineers to URS Corporation.

Pipelines

NCFCWCD South Segment Sewer Replacement, Napa, California: Dr. Storesund served as a field engineer, observing construction of a 54-inch to 66-inch diameter sanitary sewer line in Napa. The project, separated into two segments, realigned and replaced approximately 4,500 lineal feet of mainline sewer outside the river flood plain as part of the Napa River Project. Construction observations pertained to pressure grouting ground improvement, pipeline subgrade inspections, pipe bedding and backfill observations, trench backfill density testing, AC pavement density testing, concrete sampling, pipe segment seal testing, and observations of lightweight concrete backfill of old sewer line.

PG&E Line 131 Pigging Project, Alameda County, California: Dr. Storesund served as field engineer, coordinating and conducting geotechnical exploratory test pits for a new PG&E maintenance access facility to service two 18-inch, high-pressure, gas mains. Site improvements included an enlarged access road and maintenance pad, rock cut slopes, and minor pipeline realignment.

Newby Island Gas Transmission Pipeline, Milpitas, California: Dr. Storesund served as a field engineer providing construction observations on trench backfill operations on a landfill methane gas recovery pipeline installed at the base of an existing Santa Clara County Flood Control Levee. Trench backfill consisted of lightweight concrete slurry, designed to isolate the installed pipeline and protect the structural integrity of the existing levee system.

South Transmission System Project Tanks, Sonoma County, California: Dr. Storesund served as a field engineer during the geotechnical exploration of this project. Seven water tank sites were evaluated during the field operations. Geotechnical explorations included seismic refraction studies, vertical soil borings, and geologic reconnaissance mapping.

Granada Sanitary District CIP, San Mateo County, California: Dr. Storesund organized and performed the field exploration for this project which consisted of "jack and bore" operations under Highway 1 in Granada. Engineering foundation design recommendations were generated for temporary shoring required during the construction process.

Earthquake Fault Explorations

North Livermore Properties, Livermore, California: Dr. Storesund served as a support field engineer for the project geologist on this fault rupture hazard study in Livermore. Tasks included geologic mapping, study of stereo-paired aerial photographs, and an extensive fault trenching investigation. Dr. Storesund was responsible for the setup of the fault trench shoring and dewatering pumping system design. Dr. Storesund also assisted the project geologist in field logging the excavated fault trench.

Centex Homes' Farber Property, Livermore, California: Dr. Storesund served as a field engineer, assisting the project geologist, for a fault rupture hazard study for a proposed residential development located within the Alquist-Priolo Special Studies Zone for the Greenville Fault. The investigation included excavation and detailed logging of two trenches, totaling over 800 feet in length.

Alameda County Sherriff's Facility Landslide Assessment, Hayward, California: Dr. Storesund served as a field engineer providing assistance during the fault trenching phase of the field investigation. The project involves demolishing the existing Animal Control Facility and constructing a new 160,000 square foot building that will include facilities for the Sheriff and Coroner and a parking garage for about 500 cars. The proposed building will be a multi-level structure, and the garage will extend one or two levels below grade. The structure will be a critical facility and must remain operational following an earthquake. Other improvements will include driveways, a visitor's parking lot, underground utilities and landscaping. Preliminary schematics suggest that the facility will occupy the entire 4-acre site. The project included evaluating potential landslide and surface fault rupture hazards at the site.

Osgood Road Fault Trench, Fremont, California: Dr. Storesund served as the project manager responsible for the organization and implementation of backfill operations on a fault rupture hazard study for a proposed new PG&E gas main alignment in Fremont within a BART right-of-way zone. A total of three trenches (totaling approximately 350 linear feet and 12 feet deep) were excavated and backfilled according to BART specifications.

Dumbarton Quarry and Associates, Hayward, California: Dr. Storesund served as a support field engineer for the project geologist on this fault rupture hazard study project at the La Vista Quarry in Hayward. Tasks included geologic mapping, study of stereo-paired aerial photographs, and an extensive fault trenching investigation. Dr. Storesund was responsible for the setup of the fault trench shoring and dewatering pumping system design. Dr. Storesund also assisted the project geologist in field logging the excavated fault trench

LBL-50X AP Fault Study, Berkeley, California: Dr. Storesund acted as a field engineer for the fault location study for a proposed 6-story building to be constructed on a steep hillside within the State designated Fault Rupture Hazard Zone for the active Hayward Fault. The steep, vegetated slope made excavation of continuous trenches difficult and numerous trenches had to be excavated to provide appropriate coverage. No evidence of active or potentially active faulting was encountered in the trenches.

Transportation

Caltrans I-238 Widening Project, Alameda County, California: Dr. Storesund served as both a field engineer responsible for the coordination and implementation of the field investigation program and a staff engineer performing design calculations and analyses. The I-238 project includes the widening of the freeways and related replacement or improvement of existing connectors, overcrossings, and railroad underpasses. Existing embankments are to be widened which requires installation of concrete and MSE retaining wall. Field investigations performed for the project included an extensive subsurface exploration program utilizing continuous flight solid and hollow stem augers, rotary wash borings and Cone Penetration Test (CPTs) soundings. In addition, available subsurface data from previous investigations was reviewed as were published geologic and soil survey data. The field exploration program was complemented with geotechnical laboratory testing. Following completion of the field investigation and laboratory testing, analyses were performed to evaluate geotechnical engineering aspects of project, particularly settlement and liquefaction hazard studies.

Caltrans I-880/Mission Boulevard Widening Project, Alameda County, California: Dr. Storesund served as a support staff engineer for the I880/Mission Boulevard Widening Project. The project involved over 100 test borings, geotechnical laboratory analyses, engineering foundation design recommendations, flexible pavement design, and seismic design criteria for five roadway bridges and one railroad bridge. Other improvements included: a cut and cover tunnel box, box culverts, retaining walls, and ancillary structures.

Caltrans Guadalupe Highway 87 Renovation, San Jose, California: Dr. Storesund served as a field engineer providing AC pavement density testing Quality Control services during the construction phase of this project. The project included widening of the existing Highway 87, construction of a new overpass over Highway 101, and other retaining walls and street improvements.

Port of Oakland's Oakland Airport Expansion, Oakland, California: Dr. Storesund served as a field engineer for this roadway widening and expansion project, providing construction observations and testing services for, utility trench backfill compaction testing, roadway subgrade and base rock density testing, AC pavement testing, and concrete sampling. The project consisted of the construction of new roadway over and underpasses, roadway widening, and utility upgrades.

Petaluma Transit Mall, Petaluma, California: Dr. Storesund was the project engineer for this streetscape project in Petaluma who was responsible for the organization and execution of the field exploration program as well as generating design recommendations. The proposed streetscape improvements included sidewalks, PCC and AC pavements, information kiosks, and lighting standards.

Reid-Hillview Airport, San Jose, California: Dr. Storesund was the field engineer for this runway rehabilitation project. Dr. Storesund was responsible for quality control observations related to pavement section construction.

Nut Tree Airport, Fairfield, California: Dr. Storesund was a field engineer for this runway rehabilitation and expansion project in Fairfield. Dr. Storesund was responsible observations during new runway grading operations, pavement section construction, and provided support during asphalt content laboratory analyses.

First Street Bridge Replacement Project, Napa, California:
Dr. Storesund served as the project engineer for this project which involved the First Street Bridge Replacement Project located in Napa, California. Dr. Storesund coordinated and managed Fugro's field operation exploration program, performed the field exploration, analyzed the collected data, and provided a preliminary geotechnical design report.

Independent Technical Reviews (ITR)

Pier 36/Brannan Street Wharf Demolition, City and County of San Francisco, California: Dr. Storesund served as the project manager and project engineer for this technical review (on behalf of the San Francisco District US Army Corps of Engineers), which consisted of a geotechnical evaluation of submitted calculations and plans. The project entails the demolition of an existing wharf to make room for the construction of a new public open space wharf and associated boating facilities.

California WaterFix Intake Structures, Sacramento County, California: Dr. Storesund provided expert testimony with regards to feasibility of utilization of drilled pier foundations in lieu of driven pre-cast piles for proposed intake structures associated with the California Water Project.

Hamilton Wetland Restoration Levee Raising Project, Novato, California: Dr. Storesund served as a project engineer for this technical review (on behalf of the San Francisco District US Army Corps of Engineers), which consisted of a geotechnical evaluation of submitted calculations, plans, and specifications. The project entails the raising of existing flood protection levees to account for settlements (experienced and anticipated) to the levees.

Marysville Unified School District Pipeline Review, Marysville, California: Dr. Storesund, as part of CCRM, performed a review of a natural gas pipeline risk assessment (per California Department of Education protocols) for the Marysville Unified School District.

Twin Rivers Unified School District Pipeline Review, Sacramento, California: Dr. Storesund, as part of CCRM, performed a review of a natural gas field risk assessment (per California Department of Education protocols) for the Twin Rivers Unified School District.

Milford Township School District Pipeline Review, Milford, Pennsylvania: Dr. Storesund, as part of CCRM, performed a review of a natural gas field risk assessment for the Milford Township School District on the citing of a new school.

Miami-Dade Back Bay Coastal Storm Risk Management (CSRM) Integrated Feasibility Report and Environmental Impact Statement (EIS), Miami-Dade County, Florida: Dr. Stroresund served as an expert reviewer on behalf of the Battelle Foundation for this USACE IEPR. The study area is Miami-Dade County which is located on the southeast coast of Florida. The county includes the City of Miami and has a population of approximately 2.8 million people, making it the most populous county in Florida and the seventh most populous in the United Sates. The average elevation of the county is 6 feet above sea level. Based on its low lying topography and dense population, the Miami-Dade County area is recognized for risks associated with sea level rise and coastal storms. The study area will continue to be at risk of the effects of coastal storms in the future. In addition to damages to structures and critical infrastructure, there is a significant life safety component that should be considered due to the vulnerability of the population and study area to flooding impacts as well as potential vulnerability of evacuation routes. Study risks include the accurate projection of sea level rise over the period of analysis and the potential limited ability to use existing models to analyze conditions in the study area due to unique geologic and hydrodynamic conditions.

McCook Levee, Illinois, Continuing Authorities Program, Section 205, Small Flood Risk Management and Integrated Environmental Assessment: Dr. Stroresund served as an expert reviewer on behalf of the Battelle Foundation for this USACE IEPR for the McCook Levee study, which involved flood risk reduction measures on two portions of an existing levee (Southern McCook Levee & Northern McCook Levee) as well as a nearby levee (West Lyons Levee). The Alternatives considered during the feasibility study included modification of the drainage of the McCook Ditch partnered with either full or segmented rehabilitation of the northern portion of the McCook Levee, rehabilitation or elevation of the West Lyons Levee, as well as non-structural measures.

Houston Ship Channel Expansion Channel Improvement Project, Harris, Chambers, and Galveston Counties, Texas. Draft Integrated Feasibility Report – Environmental Impact Statement: Dr. Stroresund served as an expert reviewer on behalf of the Battelle Foundation for this USACE IEPR for the Houston Ship Channel (HSC), Galveston Harbor and Channels, Galveston Entrance Channel, and the Texas City Ship Channel. These channels are integrally connected to the overall navigation system of the Galveston Bay area. The HSC provides access to various private and public docks and berthing areas associated with Port Houston. It is the longest major navigation channel within the HSC system, spanning Harris, Chambers, and Galveston Counties, Texas. The HSC project consists of an existing 50-mile long deep-draft navigation channel, four deep-draft tributary channels, and one shallow draft tributary channel. Several other minor tributary channels also intersect the HSC, including South Boaters Cut, North Boaters Cut, and Five Mile Cut.

Little Colorado River at Winslow, Navajo County, Arizona Flood Risk Management Feasibility Study: Dr. Stroresund served as an expert reviewer on behalf of the Battelle Foundation for this USACE IEPR for the Little Colorado River (LCR) at Winslow General Investigations study undertaken to evaluate structural and non-structural flood risk management measures to reduce the risk of flooding in the City of Winslow and vicinity. The study's purpose was to investigate problems and opportunities and potential alternatives to provide flood risk management for the City of Winslow and vicinity. Potential flood risk management solutions included both structural and non-structural measures. Structural measures included levee rehabilitation, new levees, channel improvements to increase conveyance capacity, grade control structures, bank stabilization, and on-line or off-line detention facilities. Non-structural floodplain management measures included assisting communities with floodplain management and flood warning systems in areas where needed. In addition, floodproofing, buyout, relocation, and dry flood-proofing were considered.

Denver Urban Waterways Restoration Feasibility Study and Environmental Impact Statement, Adams & Denver Counties, Colorado: Dr. Stroresund served as an expert reviewer on behalf of the Battelle Foundation for this USACE IEPR for a study along the South Platte River through Denver, Colorado to provide a functioning habitat corridor for migratory birds, and wetland and aquatic species, and to address flood risk issues along the Harvard Gulch and Weir Gulch tributaries to the river. A variety of management measures were developed that would address one or more of the planning objectives. These measures were evaluated and then screened. Alternative plans were then developed comprising one or more of the management measures. Ecosystem restoration alternatives were developed for the South Platte River, while structural and non-structural flood risk management alternatives were developed for the Weir and Harvard Gulches.

Princeville, North Carolina Flood Risk Management Feasibility Study Integrated Feasibility Report and Environmental Assessment: Dr. Stroresund served as an expert reviewer on behalf of the Battelle Foundation for this USACE IEPR for the proposed Princeville flood protection improvement project. The tentatively selected plan (TSP) included measures to extend the existing levee and raise U.S. Highway 258 and Shiloh Farm Road north of the Town of Princeville to create a barrier to circumvention of the existing levee, as well as ramping residential, farm, and commercial driveways and subdivision streets to meet the new elevation. The TSP also includes non-structural measures consisting of an updated flood warning and evacuation plan, continued floodplain management and updating of local building and zoning codes, a flood risk management education and communication plan for both the community and local schools, and flood warning measures, all of which were ultimately deemed essential to an adequate flood risk management strategy for the Town of Princeville. The estimated cost of the TSP is $21,096.00 million.

Dredged Material Management Plan (DMMP) Update for Baltimore Harbor and Channels, Maryland: Dr. Stroresund served as an expert reviewer on behalf of the Battelle Foundation for this USACE IEPR for the Baltimore Harbor and Channels project includes a series of 50-foot deep channels from the Atlantic Ocean through Chesapeake Bay and into the Port of Baltimore on the Patapsco River; 35 foot channels from the mouth of the Patapsco, up Chesapeake Bay to the Chesapeake and Delaware Canal; and assorted branch channels and anchorages. Together, the Port includes three separate authorized projects, which together generate, on average, 3.2 million cubic yards (cy) of material each year as part of normal maintenance.

Risk Assessments

Multiple Lines of Defense, Coastal Louisiana: Dr. Storesund worked in conjunction with the Lake Pontchartrain Basin Foundation to conduct an initial qualitative risk assessment of the hurricane flood protection system in the greater New Orleans area. The assessments follow the Quality Management Assessment System (QMAS) protocols. The assessment provides the basis for initial definition of the system, stakeholders, and identifies primary Factors of Concern. This assessment is the pre-cursor to detailed quantitative risk assessments.

Oroville Dam Comprehensive Needs Assesment, Butte County, California: Dr. Storesund was appointed by California Senator Jim Nielsen and California Assemblyman James Gallagher to serve as the Risk Management representative to the community Ad Hoc Committee to review outcomes from the Oroville Dam Comprehensive Needs Assessment following the catastrophic failure of the Oroville Dam primary spillway in February 2017. Dr. Storesund

Tsunami Risk-Based Design Committee, Northern California: Dr. Storesund is the Chair of this committee, sponsored by the ASCE San Francisco Section. The aim of the Working Group is to accomplish the following: (1) Formulate a group of appropriate stakeholders (local, county, state, federal levels); (2) Conduct a summary of 'best practices' and available resources (perhaps through a series of workshops) (a) Risk standards (b) Hazard studies (reports, maps, etc) (c) Design standards; (3) Develop Policy Statement (goals based on best practices and available info); and (4) Develop Guidelines for Risk-Based Tsunami Design Criteria in Coastal California.

PG&E Risk Management Framework Assessment: Dr. Storesund served as the project manager on an assessment committee to provide insights on their risk management framework. The insights included: (a) is the right RMF being used for the stated goals?; (b) are all significant RMR relationships being captured?; (c) strategies for visualizing and mapping risk; (d) identifying the 'right' risks and prioritizing; and (e) RMF resilience and maturity. Potential actionable outputs include: (1) reference practices (organizational examples); (2) listing of RMF activities to expand and advance; (3) listing RMF activities to modify/reconfigure; and (4) RMF performance metrics (i.e. targeted monitoring and review, leading/lagging indicators).

Oroville Dam Comprehensive Needs Assessment Ad-Hoc Committee: Dr. Storesund served as a community volunteer/representative with respect to risk assessment and management for the Oroville Dam afety review termed "Comprehensive Needs Assessment." Following the 2017 Oroville Spillway Incident, DWR made commitments to the Oroville community, federal and state dam safety regulators, the Federal Energy Regulatory Commission (FERC) and the California Division of Safety of Dams (DSOD), to assess the facilities within the Oroville Dam Complex to identify further dam safety and operational needs. In addition, DWR committed to identifying potential measures to address those needs and reduce dam safety risks. In January 2018, DWR initiated the Oroville Dam Safety Comprehensive Needs Assessment (CNA) and the report published in November 2020. enator Jim Nielsen and Assemblyman James Gallagher appointed a group of community members to represent the community during the CNA. The Ad Hoc Community group's role was primarily to communicate accurate information and context about elements of the CNA under consideration – and the final document – to the stakeholders and interest groups that they represent. The Ad Hoc Group also provided informed community and stakeholder perspectives to the IRB as the Oroville Dam CNA was developed. The Ad Hoc Group received questions about the CNA from the community and interested parties and communicated relevant questions or concerns to the IRB.

Forensic Evaluations

Bayer Communications Building, Berkeley, California: Dr. Storesund served as the field engineer to survey and evaluate settlements in the Bayer Communications Building, which was the 'nerve center' for all communication operations at the facility. Site surveys consisted of floor level surveys, review of historical soil exploration programs, and review of nearby construction activities. The study found that excavation operations associated with the upgrade of a sewer line immediately adjacent to the structure led to lateral stress relaxation and vertical displacement of the footings.

Southeast Louisiana (SELA) Drainage Litigation, New Orleans, Louisiana: Dr. Storesund provided forensic engineering services relative to damages resulting from construction of new drainage facilities in the larger uptown New Orleans area. Damages included physical damage to structures as well as loss of use and enjoyment. Overall project construction cost for all SELA phases was approximately $600 million. Damage claims were on the order of $75 million.

Oroville Dam Cases, Oroville, California: Dr. Storesund was retained by PG&E to provide forensic engineering services relative to the 2017 failure of the Oroville Dam Primary Spillway.

Walker v. Tran, Oakland, California: Dr. Storesund provided forensic engineering services associated with a dispute related to a failed property line retaining wall.

Alford v. EBMUD, Orinda, California: Dr. Storesund provided forensic engineering services associated with a landslide dispute.

City of Issaquah v. Ora Talus 90, Issaquah, Washington: Dr. Storesund provided forensic engineering services associated with a landslide dispute.

Vittimberga Landslide, Orinda, California: Dr. Storesund provided forensic engineering services associated with a landslide dispute.

Tappen Terrace Landslide, Orinda, California: Dr. Storesund provided forensic engineering services associated with a landslide dispute.

Bear Creek Road Landslide, Boulder Creek, California: Dr. Storesund provided forensic engineering services associated with a landslide dispute.

Zanotti Residence, Cupertino, California: Dr. Storesund provided forensic engineering services associated with a landslide dispute.

Slezak Landslide, El Sobrante, California: Dr. Storesund provided forensic engineering services associated with a landslide dispute.

Shaw v Privilige Underwriters et al, New Orleans, Louisiana: Dr. Storesund provided forensic engineering services associated with a contruction-induced vibration dispute.

Paradise Drive Distressed Structure, Tiburon, California: Dr. Storesund provided forensic engineering services with regards to construction-induced vibration damage on this residential structure.

Bell Carter Foods Distressed Structure, Lafayette, California: Dr. Storesund organized and performed the foundation exploration which involved drilling soil test borings within the structure using portable hydraulic drilling equipment. The purpose of the project was to identify the foundation instability mechanism and provide mitigation strategies.

Badger Road, Sonoma County, California: Dr. Storesund provided forensic services for a residential structure experiencing distress as a result of creek-induced erosion and scour.

The Preserves, Redwood City, California: Dr. Storesund provided forensic engineering services for a group of residential structures experiencing excessive differential settlements. The structures were constructed on the bay margin, on top of Young Bay Mud. Analyses included 3D laser scanning, settlement uncertainty analyses, and mitigation analyses.

Silverado Trail Landslide/Fault Litigation, Napa County, California: Dr. Storesund provided forensic engineering analyses and exert testimony in with regards to a claim of varying site conditions based on presence of an unmapped landslide and/or fault at the site of a residential development.

Beauregard Creek Distressed Embankment and Spillway, Santa Clara County, California: Dr. Stoeresund provided forensic engineering analyses with regards to a claim o f unlawful and substation diversion and change in the bed, channel, and bank of a natural creek.

Mississippi River Gulf Outlet Wave-Induced Erosion, St. Bernard Parish, Louisiana: Dr. Storesund provided state of the art engineering analyses examining the contribution of damage to the Mississippi River Gulf Outlet levees as a result of wave action from Hurricane Katrina in 2005. The evaluations required the development of a validated method to assess the plausible range of erosion susceptibilities due to wave impact and run-up. These evaluations were published in the ASCE Journal of Waterway, Port, Coastal and Ocean Engineering.

Investigation of the Greater New Orleans Area Flood Defense System Failure, New Orleans, Louisiana: Dr. Storesund was a consultant for the National Science Foundation sponsored investigation of the failure of the New Orleans Flood Defense System. He aided in the initial field reconnaissance to survey system damage and contributed to the technical analyses evaluating system failure mechanisms. He aided in the use of state of the art methods for erosion sampling and testing as well as LiDAR remote sensing survey methods on the Mississippi River Gulf Outlet levees. Copies of the findings from the evaluation can be accessed at: www.ce.berkeley.edu/~new_orleans.

Upper Jones Tract Levee Failure, San Joaquin County, California: Dr. Storesund provided engineering evaluations associated with the June 2004 breach of the Upper Jones Tract Levee in conjunction with Dr. J. David Rogers. The evaluations included bathymetric surveys, RTK GPS surveys, development of digital terrain models using bathymetry and Aerial LiDAR data, hydraulic modeling, and levee failure analyses (seepage, slope stability). Dr. Storesund was responsible for: project management, planning, and tracking; geotechnical engineering evaluation and analyses; hydrodynamic evaluations; general engineering evaluations; standard of care evaluations; technical data evaluation; computer graphics/animations; digital cartography; scientific and technical writing. Dr. Storesund provided deposition and trial testimony.

East Bank Industrial Area (Lower 9th Ward), New Orleans, Louisiana: Dr. Storesund provided engineering support services to Dr. Robert Bea and Dr J. David Rogers for a field exploration program that included geoprobes, CPTs, and pump testing of the onsite "swamp/marsh" material in order to back calculate the permeability of this deposit. The work was performed in close coordination with all experts (plaintiffs and defense). Dr. Storesund served as the project manager for his $1.3 million project (completed in 3 months). Dr. Storesund was responsible for: project management, planning, and tracking; geotechnical engineering evaluation and analyses; hydrodynamic evaluations; general engineering evaluations; standard of care evaluations; technical data evaluation; computer graphics/animations; digital cartography; scientific and technical writing.

PNG Landslide, Papua New Guinea: Storesund Consulting worked in conjunction with Prof. J. David Rogers, Prof. Calvin Alexander, and Mr. Eldon Gath to assess the causal mechanism(s) of a landslide in Papua New Guinea. Available data was reviewed and a field reconnaissance trip to the failure site was performed in summer of 2012. Dr. Storesund provided geotechnical and liar data interpretation services.

Oso Landslide Litigation, Washinton State: Dr. Storesund served as an Expert to the State of Washington's Attorney General's Office in response to the catastrophic March 22, 2014 landslide that ripped through the sleepy neighborhood of Steelhead Haven, WA; tragically resulting in the deaths of 43 individuals. Steelhead Haven is located in Northern Washington State, approximately 60 miles north of Seattle. The engagement involved examining: the causation of the Oso Landslide; the predictability of the Oso Landslide in the time frame of pertinent DNR FPA approvals; the predictability of the runout of the Oso Landslide; and the impact of pertinent DNR approved timber harvests on the Whitman Bench with regard to the causation of the Oso Landslide.

LiDAR Surveys

Sunol Dam Removal, Alameda County, California: In 2006, the San Francisco Public Utilities Commission removed Sunil dam to improve fish passage, restore a self-sustaining population of steelhead to the Alameda Creek watershed, and reduce or eliminate an existing public safety hazard. The dam contained an estimated 37,000 yd^3 of impounded sediment. To create a baseline for future monitoring of impounded sediment transport, a combination of Aerial Liar, Terrestrial LiDAR, and conventional survey data was compiled and synthesized to generate a three dimensional model of the study area. High resolution characterization of the impounded sediments was accomplished using Terrestrial LiDAR, with an approximate point spacing of centimeters.

O'Shaugnessy Dam (Hetch Hetchy) & Spillway Assessment, Tuolumne County, California: Storesund Consulting provided Terrestrial LiDAR survey of the dam to facilitate geologic mapping of rock structure (joints, strikes, dip) for erosion vulnerability assessments. Use of this remote sensing technology enabled high resolution data and elimination of dangerous rapel-based reconnaissance.

Balch Diversion Dam, Fresno County, California: Storesund Consulting provided Terrestrial LiDAR survey of the Balch Diversion dams to facilitate geologic mapping of rock structure (joints, strikes, dip) for erosion vulnerability assessments. Use of this remote sensing technology enabled high resolution data and elimination of dangerous rapel-based reconnaissance.

Balch Afterbay Dam, Fresno County, California: Storesund Consulting provided Terrestrial LiDAR survey of the Balch Afterbay dams to facilitate geologic mapping of rock structure (joints, strikes, dip) for erosion vulnerability assessments. Use of this remote sensing technology enabled high resolution data and elimination of dangerous rapel-based reconnaissance.

Spaulding #1 Dam, Nevada County, California: Storesund Consulting provided Terrestrial LiDAR surveys of the Balch Diversion dams to facilitate geologic mapping of rock structure (joints, strikes, dip) for erosion vulnerability assessments. Use of this remote sensing technology enabled high resolution data and desktop-based mapping and analysis.

Spaulding #2 Dam, Nevada County, California: Storesund Consulting provided Terrestrial LiDAR surveys of the Balch Diversion dams to facilitate geologic mapping of rock structure (joints, strikes, dip) for erosion vulnerability assessments. Use of this remote sensing technology enabled high resolution data and desktop-based mapping and analysis.

Hour House Dam, Sierra County, California: Storesund Consulting provided Terrestrial LiDAR surveys of the Balch Diversion dams to facilitate geologic mapping of rock structure (joints, strikes, dip) for erosion vulnerability assessments. Use of this remote sensing technology enabled high resolution data and desktop-based mapping and analysis.

Log Cabin Dam, Yuba County, California: Storesund Consulting provided Terrestrial LiDAR surveys of the Balch Diversion dams to facilitate geologic mapping of rock structure (joints, strikes, dip) for erosion vulnerability assessments. Use of this remote sensing technology enabled high resolution data and desktop-based mapping and analysis.

New Bullards Bar Dam, Yuba County, California: Storesund Consulting provided Terrestrial LiDAR surveys of the Balch Diversion dams to facilitate geologic mapping of rock structure (joints, strikes, dip) for erosion vulnerability assessments. Use of this remote sensing technology enabled high resolution data and desktop-based mapping and analysis.

El Sobrante Landslide, El Sobrante, California: Storesund Consulting performed ground based lidar scanning of a landslide to characterize the volume of displaced material and establish basemap for landslide mitigation designs.

Cordelia Pipeline Landslide, Cordelia, California: Storesund Consulting performed ground based lidar scanning of a landslide to characterize the volume of displaced material and establish basemap for landslide mitigation designs.

Genentech Facilities, South San Francisco, California: Dr. Storesund provided Terrestrial LiDAR scanning services for Genentech to map existing structural conditions as well as mechanical, electrical, and plumbing (MEP) facilities to facilitate BIM modeling and routing of new utilities (using 'clash detection').

Pit Dam 3 Mapping, Burney, California: Storesund Consulting provided a Terrestrial LiDAR scan of select areas at the PGE Pit Dam 3 facility to aid in the evaluation of a fault system at the site. A high-accuracy point cloud was rendered of the fault are, allowing field geologists to geolocate fault features with high accuracy. Additionally, fault trenches were scanned and rectified orthoimages were rendered to aid in mapping fault trace features.

Quadrus Hill, Menlo Park, California: Storesund Consulting performed Terrestrial LiDAR scanning services for this office complex in a landscaped boulder area where high-precision mapping of boulder features was required to correctly situate a new deck.

Intarcia, Fremont, California: Dr. Storesund provided Terrestrial LiDAR scanning services for this project to map existing structural conditions as well as mechanical, electrical, and plumbing (MEP) facilities to facilitate BIM modeling and routing of new utilities (using 'clash detection').

1245 Market, San Francisco, California: Dr. Storesund provided Terrestrial LiDAR scanning services for this project to map existing structural conditions as well as mechanical, electrical, and plumbing (MEP) facilities to facilitate BIM modeling and routing of new utilities (using 'clash detection').

Veterans Administration Facility, Mather, California: Dr. Storesund provided Terrestrial LiDAR scanning services for this project to map existing structural conditions as well as mechanical, electrical, and plumbing (MEP) facilities to facilitate BIM modeling and routing of new utilities (using 'clash detection').

Yosemite Slough Wetland Erosion Study, San Francisco, California: Storesund Consulting performed annual erosion/deposition monitoring using Terrestrial LiDAR for the wetland restoration project. Hydrodynamic modeling was performed estimating erosion/deposition. This monitoring program provided a high resolution digital terrain model by which to measure erosion/deposition across the restoration area (3 acres).

Causby Mine Survey, Stanislaus County, California: Dr. Storesund served as the project manager and project engineer for this LiDAR mapping project of an abandoned mine tunnel for the U.S. Forest Service. Mapping consisted of the entrance and exit (for construction access) as well as the interior of the tunnel (for volume estimates and layout purposes). State of the Art LiDAR processing software was used to model the interior of the tunnel in 3D.

Tocaloma Backwater Project, Marin County, California: Dr. Storesund provided RTK GPS and Terrestrial LiDAR surveys for this backwater restoration project for the County of Marin. The work was provided for Balance Hydrologics (who performed the design). Aerial LiDAR was merged with the Terrestrial LiDAR to create a full 3D terrain model of the restoration area.

Arroyo de la Laguna, Alameda County, California: Arroyo de la Laguna is part of the stream system that includes the Dublin, Pleasanton, Livermore, as well as upland portions of northern Santa Clara County. Watershed hydrology and channel function have been historically impacted by urbanization (including drainage and flood control), roads, railroads, gravel mining, and the construction of Del Valle Reservoir, resulting in channel incision on the order of six meters. Severe stream bank erosion was identified on the outer bends of an "S" curve of the Arroyo de la Laguna Creek. Terrestrial LiDAR was used to generate cost-effective, high-accuracy mapping of as-built conditions of newly completed stream and river restoration projects, thereby establishing a baseline by which future monitor efforts can evaluate overall project performance through time.

Salt Pond A21, Alameda County, California: Dr. Storesund performed Terrestrial LiDAR survey for researchers at the University of California at Berkeley on this 160-acre wetland restoration project in Fremont, California. The surveys were used to monitor sediment accretion, scour, and erosion progression within this recently breached salt pond.

Tennessee Hollow, San Francisco, California: A storm drain creek daylighting project was completed at the San Francisco Presidio. LiDAR surveys were used to establish baseline topography following completion of construction in January of 2006. Subsequent surveys were performed to evaluate vegetation growth rates and growth zones. The baseline survey is anticipated to serve as an overall baseline by which future channel stability can be evaluated.

AMR, Roseville, California: Storesund Consulting provided high-resolution RTK GPS topographic survey and Terrestrial LiDAR surveys of vernal pools to provide a baseline micro-topographic terrain model which became the design 'template' for restoration of 150 acre vernal pool site.

Cache Creek, Woodland, California: Terrestrial LiDAR surveys were conducted at two specific locations where the creek channel shifted into the creek bank, causing the formation of a tall vertical bank. The terrestrial LiDAR surveys were conducted to map the conditions of the vertical bank. Additionally, aerial LiDAR surveys were also performed at this site and future studies will compare and contrast the resolution and accuracy between these two methods at this site.

Goodwin Creek, Oxford, Mississippi: The Goodwin Creek watershed is organized and instrumented for conducting extensive research on upstream erosion, stream erosion and sedimentation, and watershed hydrology. Land use and management practices that influence the rate and amount of sediment delivered to streams from the uplands range from timbered areas to row crops. About 13 percent of the watershed total area is under cultivation and the rest in idle pasture and forest land. Terrestrial LiDAR surveys were performed at one location in an attempt to evaluate the feasibility of utilizing LiDAR to measure and quantify sediment transport and vertical bank retreat rates.

Coldwater Creek, Mississippi: Coldwater Creek is part of a United States Department of Agriculture National Sedimentation Laboratory research watersheds. The quantity and quality of aquatic habitats along the lowland floodplain rivers in agricultural landscapes are in steep decline as a result of nonpoint source pollution. Terrestrial LiDAR surveys were performed at the site of an ephemeral gully in order to ascertain the feasibility of mapping these features with LiDAR to develop 3D surfaces by which more detailed analyses can be performed (including erosion rates) as opposed to the traditional cross-sectional survey method, which may not fully capture the behavior of the site.

Tolay Lake, Petaluma, California: This collaborative effort between the Sonoma County Parks and Recreation, Ducks Unlimited, and United States Geological Survey, will restore a seasonal lake on Tolay Creek in Sonoma County. Existing agricultural fields will be converted to a county park and will serve as a duck reserve in the fall and winter. Terrestrial LiDAR surveys were preformed to develop a detailed topographic map of the project site. Over 200 acres were surveyed in two days.

Ben Mar, Benicia, California: Dr. Storesund performed Terrestrial LiDAR survey for the United States Geological Survey on this 25-acre wetland restoration project in Benicia, California as part of a Caltrans mitigation project. The surveys were used to monitor sediment accretion within the completed restoration area.

Tilden Step Pool, Berkeley, California: Storesund Consulting worked in conjunction with Dr. Anne Chin (University of Colorado, Boulder) by mapping as-built conditions of a step pool sequence in Tilden Park. Change analyses will be performed over three storm events to ascertain step pool stability.

Colorado Wildfire Step Pool Evaluation, Colorado: Storesund Consulting worked in conjunction with Dr. Anne Chin (University of Colorado, Boulder) by analyzing terrestrial LiDAR scans of study areas before and after storm events to ascertain step pool stability.

Verona Bridge Creek Restoration, Pleasanton, California: Storesund Consulting performed a Terrestrial LiDAR survey of this in-stream habitat enhancement and slope stability restoration project in Pleasanton. The project was designed by the National Resource Conservation District.

Tubb, Vallejo, California: Dr. Storesund performed Terrestrial LiDAR survey for the United States Geological Survey on this 60-acre wetland restoration project in Sonoma County, California. The surveys were used to monitor sediment accretion within the completed restoration area.

Rodeo Creek, Hercules, California: LiDAR scanning services were performed on the newly acquired Rodeo Creek East Bay Regional Park property in Rodeo, California. Rodeo Creek was incised 20-30 feet below the floodplain and heavily vegetated, making it difficult to perform conventional topographic surveys. As a result of the LiDAR surveys, a 3D surface, topography, and cross-sections over a 1,000 foot stretch of creek was cost-effectively mapped.

Winfield Pin Oaks Levee Investigation, Winfield, Missouri: The Winfield Pin Oak levee is maintained by the Cap Au Gris Drainage and Levee District. The levee system (Figure 23) is estimated to prevent flooding of the protected area (493 hectares) up to a 14-year return period flood event on the Mississippi River. This site was overtopped for an extended period of time and breached as a result of overtopping-induced erosion. Terrestrial LiDAR surveys (georeferenced using RTK GPS) were performed in October 2008 for subsequent forensic analyses.

Norton Woods Levee Investigation, Elsberry, Missouri: The Elsberry levee at Norton Woods is maintained by the Elsberry Drainage District. This breach was the result of either a through-seepage induced or overtopping-induced (low crest elevation) failure. High water marks observed in the field indicate that the floodwaters did not exceed the general levee crest elevation. Terrestrial LiDAR surveys (georeferenced using RTK GPS) were performed in October 2008 for subsequent forensic analyses.

Kickapoo Levee Investigation, Elsberry, Missouri: The Elsberry levee at Kickapoo is maintained by the Elsberry Drainage District. This breach was reported by local residents to have been the result of through-seepage in the roadway base course that traversed the levee crest. The extents of levee erosion were generally limited to the pre-breach roadway alignment. Terrestrial LiDAR surveys (georeferenced using RTK GPS) were performed in October 2008 for subsequent forensic analyses.

San Francisco Pier 9, San Francisco, California: Storesund Consulting provided Terrestrial LiDAR scanning services for this renovation project to enable a 3D check against existing as-built documentation and facilitate BIM modeling. The new facility is a 3D printing center for Autodesk.

AT&T Facility MEP Scanning, California: Storesund Consulting provided Terrestrial LiDAR scanning services for this expansion project to map existing mechanical, electrical, and plumbing (MEP) facilities to facilitate BIM modeling as well as routing of a new fuel supply pipeline (using 'clash detection').

UCSF Helen Diller Center, San Francisco, California: Storesund Consulting provided Terrestrial LiDAR scanning services for this project to map existing structural conditions as well as mechanical, electrical, and plumbing (MEP) facilities to facilitate BIM modeling and routing of new utilities (using 'clash detection').

Novartis, Burlingame, California: Storesund Consulting provided Terrestrial LiDAR scanning services for this project to map existing structural conditions as well as mechanical, electrical, and plumbing (MEP) facilities to facilitate BIM modeling and routing of new utilities (using 'clash detection').

San Antonio Station, Mountain View, California: Storesund Consulting provided Terrestrial LiDAR scanning services for this project to map existing structural conditions as well as mechanical, electrical, and plumbing (MEP) facilities to facilitate BIM modeling and routing of new utilities (using 'clash detection').

Veterans War Memorial Building, San Francisco, California: Storesund Consulting provided Terrestrial LiDAR scanning services for this project to map existing structural conditions as well as mechanical, electrical, and plumbing (MEP) facilities to facilitate BIM modeling and routing of new utilities (using 'clash detection').

HWY 84 Interchange, Redwood City, California: Storesund Consulting performed a Terrestrial LiDAR scan of the HWY 84/HWY101 interchange in Redwood City to facilitate an improvement program.

Bryants Creek Levee Investigation, Elsberry, Missouri: The Elsberry levee at Kickapoo is maintained by the Elsberry Drainage District. This breach (Figure 52) occurred at the location of a duck pond that was reported to have been installed immediately adjacent to the levee system in order to attract ducks for the duck club located at the site. Terrestrial LiDAR surveys (georeferenced using RTK GPS) were performed in October 2008 for subsequent forensic analyses.

Indian Graves Levee Investigation, Quincy, Illinois: The Indian Graves Levee system is maintained by the Indian Graves Drainage District. The estimated protection level for the levee system is a 50-year return period flood and the protected area encompasses over 2,800 hectares. The sand with clay core levee system is situated immediately East of the Mississippi River. There were three breaches, two under seepage induced and one overtopping induced breach. Terrestrial LiDAR surveys (georeferenced using RTK GPS) were performed in October 2008 for subsequent forensic analyses.

Two Rivers Levee Investigation, Oakdale, Iowa: The Two Rivers Levee system is maintained by the Iowa Flint Creek Levee District No. 16. The estimated protection level for the levee system is a 100-year return period flood and the protected area encompasses approximately 7,100 hectares. The levee system is situated immediately South of the Iowa River, and west of the Mississippi River. Terrestrial LiDAR surveys (georeferenced using RTK GPS) were performed in October 2008 for subsequent forensic analyses.

Emeryville Shoreline Protection Project, Emeryville California: Terrestrial LiDAR was used to measure the volume of boulder rip-rap placed for this shoreline protection project. Due to the high void ratio and irregularity of the boulders, the very high point density of the Terrestrial LiDAR survey provided a more accurate modeling of rip-rap volume than traditional survey methods.

Dutra San Rafael Rock Quarry, San Rafael, California: The Dutra San Rafael quarry is one of the most active quarries in the Bay Area. LiDAR was used to image the physical configuration of the quarry, to create a 3D baseline survey. Subsequent LiDAR surveys will be compared against the initial baseline survey to determine material quantities as well as overall slope stability within the quarry.

Dutra Richmond Quarry, Richmond, California, California: LiDAR surveys were used to monitor a reclamation slope at the inactive Dutra Richmond Quarry. Due to the location of the slope and the geologic contacts, monitoring was required to demonstrate that no active movements are occurring and that the slope is stable. An initial baseline survey was performed in August, 2006 and subsequent surveys will be compared to the initial baseline to determine activity level.

Lower Santa Ynez, Santa Barbara County, California: The Lower Santa Ynez Bank Stabilization project was a collaborative effort with the California Conservation Corps and California Department of Fish and Game to utilize biotechnical methods to stabilize a 1,000-foot length of stream bank, adjacent to agricultural lands. Terrestrial LiDAR surveys were conducted to develop pre-project topography, as-built topography, erosion and scour quantities and estimated rates, and a coarse vegetation monitoring study.

Emery Point, Emeryville, California: Baseline Terrestrial LiDAR surveys were performed to monitor wave-induced erosion on Point Emery in Emeryville, California, which has experienced significant scour in the last 5 years. This man-made peninsula is a popular location with windsurfers and SF Bay Trail users. It is estimated that the location will be completely eroded in the next 25 years without mitigation.

Fremont Landing, Yolo County, California: The Fremont Landing project site is located along the south bank of the Sacramento River from RM 78.8 to 80.4 in one of the most hydraulically-complex portions of the river. At least five (5) major tributaries or distributaries are located within 2 miles of the site and all influence the hydrodynamics of the site. Terrestrial LiDAR surveys were performed to aid PWA develop a 2D hydrodynamic model of the project site and surrounding tributaries/distributaries. The model was used to allow examination of design issues related to fish stranding, rearing habitat, and flood conveyance.

Hamilton Wetland Restoration, Novato, California: This is a United States Army Corps of Engineers and California Coastal Commission joint project to convert over 500 acres of a decommissioned army airfield to a wetland restoration area using dredged spoil material. The area will consist of seasonal and tidal wetlands. Terrestrial LiDAR is being used to monitor fill placement and obtain volume quantities.

Mississippi River Gulf Outlet, New Orleans, Louisiana: LiDAR surveys were conducted of the southeastern completed levee segment. This survey was to serve as a baseline from which future LiDAR surveys can be conducted and analyses and evaluations of wind-induced wave impacts can be studies.

East Sand Slough Restoration, Red Bluff, California: Dr. Storesund provided terrestrial LiDAR mapping of this channel restoration project on the Sacramento River in Red Bluff, California. The LiDAR survey was integrated with existing bathymetry data. Habitat mapping using the collected LiDAR data was also conducted in general conformance with the California Rapid Assessment Method (CRAM) for Wetlands.

CZ-1 Site, Fresno County, California: Dr. Storesund provided terrestrial LiDAR mapping of this tree-root excavation and measurement study by Dr. Peter Hartsough (UC Davis) as part of his climate change research. The mapping of the tree roots provided Dr. Hartsough the ability to establish high-resolution digital root system baselines for future comparisons.

Constructed Works

Soda Bay Water Tanks Replacement Project, Lake County, California: Installation of two 60,000 gallon steel bolted water tanks and associated . Total construction value was $625,000. Client was Lake County Special Services District.

Judson Drive Water Line Replacement Project, La Honda, California: Installed a replacement water line (8 inch HDPE) along with service line connections and meters as well as new service line isolation valves and fire hydrants. Total construction value was $230,000. Client was Cuesta La Honda Guild Water District.

La Honda Water Line Upgrade Project, La Honda, California: Installed a new water line (8 inch HDPE using horizontal directional drilling methods), pressure reducing valves, domestic water supply line, and new fire hydrant. Total construction value was $135,000. Client was La Honda Fire Brigade.

Carpy Farms Irrigation, San Mateo County, California: Installed a pump intake station, electric supply and distribution system, and irrigation system for 20-acres of agricultural fields. This was a prevailing wage project. Total construction value was $440,000. Client was San Mateo County Resource Conservation District.

Moty Farms Irrigation, San Mateo County, California: Installed a pump intake station, electric supply and distribution system, and irrigation system for 20-acres of agricultural fields. This was a prevailing wage project. Total construction value was $225,000. Client was San Mateo County Resource Conservation District.

Repetto Farm Reservoir, San Mateo County, California: Enlarged a reservoir from an existing capacity of approximately 6 ac-ft to 18.5 ac-ft. The grading included excavation and removal of pond sludge, clearing of sensitive and protected species, installation of a subdrainage and dewatering system as a result of high groundwater, construction of earthen embankments, installation of an emergency spillway, and installation of irrigation pumping and distribution lines. This was a prevailing wage project. Total construction value was $450,000. Client was San Mateo County Resource Conservation District.

Little Arthur Water Conservation Project, Santa Clara County, California: Constructed five (5) seismically restrained water storage, water polishing, and water treatment systems for select residences along Little Arthur Creek. Total construction value was $725,000. Client was Trout Unlimited.

Renzel Marsh Freshwater Pond Piping, Palo Alto, California: Installed an HDPE distribution pipeline from the wastewater treatment plant to a series of treatment ponds. Total construction value was $135,000. Client was City of Palo Alto.

Bates Irrigation Tank, Morgan Hill, California: Constructed a 50,000 gallon seismically restrained water storage tank for a vineyard to modify water use by extracting and storing water during winter (high flow) months and using the stored water during summern and fall (low flow) months. Total construction value was $75,000. Client was Trout Unlimited.

Research Projects

Wildfire Risk Reduction: Framing Tools and Methods to Facilitate Integration across Organizational Perspectives and System Life Cycles to Confront Complexity of Extreme Events in the Face of Climate Change – UC Berkeley PEER

This integrated study by engineers and social scientists will advance the reach of Performance-Based Engineering (PBE) into public policy by identifying 'leading indicators' that can be used to enable the characterization and measurement of the skew between 'predicted' and 'actual/experienced' across system life-cycles phases of critical infrastructures subject to extreme events (in this case a focus on wildfires and impacts to California transportation systems) in the face of climate change. The 'expected condition' during operations can be used as a component of a 'leading indicator' program to enable early detection and correction by operators and managers to ensure the desired level of safety and reliability are achieved throughout the life cycle.

Researchers will work on a pilot test project to review current design guidelines and regulations to delineate the 'expected' performance of the electrical transmission and distribution system in California. This includes operational considerations as well as maintenance activities and frequencies. The "Performance Report" will thus become the basis of a 'gap analysis' to understand (a) vulnerability associated with non-compliance of existing performance criteria; (b) risk-reduction opportunities between increasing compliance with current guidelines; (c) risk-ranking of proposed mitigation alternatives; and (d) foundation for evaluation of potential implications associated with future extreme events. Potential collaboration with Pacific Gas and Electric, California PUC, California Governor's Office, and CA Legislature.

The tools and methods will be developed to: (1) capture and archive initial assumptions associated with the original configuration of the system {Assumption Register}; (2) establishing operational parameters that constitute the 'expected condition' of the system and associated envisioned 'decision points {Performance Manual}; (3) generating a 'feedback' mechanism across organizational perspectives to capture questions/issues/omissions associated with actual system performance relative to envisioned performance {Issue Tracker}; and (4) parameters for configuration of an organizational 'tactical team' to review 'unexpected' performance instances, analyze relative to original performance assumptions, and provide integrated response plans to system managers for implementation {Safety/Reliability Response Team}.

Three management approaches will be integrated across the system life-cycles:

- Integrity Management;
- Prevention Through People; and
- Regulation/Compliance

Information flow across Organizational Perspectives that span the 'sharp end of the spear' to the 'blunt end of the spear' will facilitated.

Homeland Security Grant Program – California Office of Emergency Services: Security Enhancement Program (SEP) Training – Chemical Standoff Detection Technologies.

Dr. Storesund was the Principal Investigator on behalf of UC Berkeley's Center for Catastrophic Risk Management on this chemical standoff education and training project.

Over 85% of U.S commerce is shipped through less than 50 domestic ports. The economic importance and visibility of ports make them attractive targets to terrorists. Attacks on vessels and port infrastructure used to move cargo could damage the U.S. economy by disrupting trade and commerce. California's ports handle over 43% of the nation's maritime commerce. According to the National Association of Manufacturers, a shutdown of California ports from terrorism or any other cause would cost the U.S. economy over $2 billion per day (https://nrf.com/resources/retail-library/the-national-impact-of-west-coast-port-stoppage). This cost does not include human losses or effects to public health.

Attacks on cruise ships docked in ports could affect the economy of host ports and cities. Sinking a cruise ship in the port or its approach lanes could block all traffic to or from the port. Port protection and security measures must provide chemical threat and risk detection at safe distances from the facility. 10 million cargo containers reach the U.S. each year. Less than five percent of incoming containers are subject to security screening. Ships and containers carrying chemicals as well as chemicals stored in ports do not have standoff protection from chemical threats and risks.

The Port of Oakland and the Port of San Francisco together account for transportation of $55.3 billion of commerce annually. The Port of Oakland is the fourth largest container port in U.S. The Port of San Diego protects Naval Base San Diego and North Island Naval Air Station, homeports of the U.S. Pacific fleet. Security risk factors in ports include the large volume of hazardous chemicals stored and transported close to urban areas. Ports can used be as gateways for WMDs to enter the country using cargo containers.

CCRM assisted in demonstrating safe standoff chemical-specific detection from up to 3 miles away while at the same time visually providing the source and dispersion of chemical releases. Both classroom chemical security training and field demonstration exercises of standoff chemical-specific detection, providing enhanced "all hazards" chemical security for not only five deepwater ports, but also surrounding urban areas that would be impacted by chemical releases caused by accidents or terrorist attacks.

Commodity Flow Studies at the ports conducted by CCRM will assess the use, storage, and transportation of hazardous chemicals and identify chemical hazards so that potentially impacted communities around ports will be able to reduce chemical threats and risks and increase resilience.

Exercises and training conducted by CCRM will follow TSA Intermodal Security Training Exercise Program (I-STEP) guidelines that test operational protocols that would be implemented in the event of a either a terrorist attack or an accident (www.tsa.gov/for-industry/intermodal-security-training-and-exercise-program). CCRM security exercises will be also consistent with the Homeland Security Exercise Evaluation Program (HSEEP; www.fema.gov/hseep).

Distributed Evaluation & Assessment Program for California's Transportation Fuel Sector (DEAP-TFS): Identifying Strategies for Reducing Vulnerability to Improve Resilience for Extreme Weather Events

The University of California at Berkeley's (UC Berkeley) Center for Catastrophic Risk Management (CCRM) is undertaking a California-wide assessment of the vulnerabilities of the Transportation Fuel Sector (TFS) in collaboration with sector and other relevant key stakeholders that will (a) identify and prioritize mitigation solutions and other resilience options into a risk reduction strategy for action; (b) delineate areas of further investigation; and (c) produce an estimate of initial costs to consumers from failure to address identified impacts.

This project will provide an initial assessment of the vulnerability of California's transportation fuel sector (TFS) to extreme weather events, working in close collaboration with TFS stakeholders so that pragmatic resilience strategies can be identified and priorities established for further investigation. We will leverage a multi-stakeholder engagement process and implement a state-of-the-art distributed information sharing framework. This structure will allow high-detail, high-accuracy data to be shared on the sector basis, while maintaining privacy and confidentiality of stakeholder data that is required for detailed internal analyses, but need not be "exposed" when sharing outcomes of analytic scenarios.

Analytic scenarios will examine vulnerabilities and resilience implications of extreme weather events such as droughts, flooding (inland, flash or coastal), wildfires, drought-induced subsidence, sea level rise, storm surge and wave dynamics, and saltwater intrusion. (Our current models will be enhanced to include riverine effects, as well extended to state-wide coverage). The analytic scenarios will be the basis for working interactively with the TFS stakeholders to identify pragmatic solutions for addressing critical impacts and implementation strategies and barriers.

There is increasing recognition of the need to assess consequences and identify priority risk-based solutions to increase the resilience of California's interdependent energy and other critical infrastructures to climate change-driven extreme weather events. This requires gaining infrastructure operator and public support to make the necessary investments for often costly and long-term upgrades, building new or more resilient infrastructure, and economic, environmental, and other policy and regulatory changes. Securing this support and enabling informed decision-making requires a "whole sector and multi-stakeholder approach" that engages and takes into account the needs of key private and public sector customers, as well as the implications for public health and safety, regional economies, and overall societal well-being.

Gaining a more in-depth and rigorous understanding of both the possible impacts and risk-based solutions to increase the resilience of California's interdependent energy and other critical infrastructures is an urgent priority. This task requires (1) dentification, prioritization, incentivizing, and justification of the mitigation actions necessary to ensure service delivery and improve resilience of systems and assets and (2) Gaining infrastructure operator and public support to make the necessary investments for often costly and long-term upgrades, building new or more resilient infrastructure, and undertaking economic, environmental, and other policy and regulatory changes.

RESIN: Contemporary infrastructure, the systems necessary to provide sustainable services within the nation's power, transportation, waste management, water, and telecommunication sectors, has become very *complex*; that is adaptive, interdependent, unpredictable, nonlinear, and dynamic. This research seeks to discover new fundamental methods to assess and manage the resilience and sustainability of such complex systems (termed 3ICIS). These methods will facilitate the characterization of both resilience and sustainability by addressing multi-infrastructure, multi-physics, multi-scale (spatial, temporal), and multi-resource phenomena that impact the likelihood of these systems failing to achieve acceptable resilience and sustainability, as well as the associated consequences. The setting selected to develop these methods is the California Sacramento Delta focusing primarily on the following four critical infrastructure services, as well as interfaces with other critical infrastructure sectors as necessary:

- Water Supply – Includes water supply system for agriculture, commercial/industry, government, and the public. Issues of importance include supply, conveyance, and quality (*note: wastewater is part of this, but not addressed here*);
- Flood Protection – Includes the structural elements (levees, floodwalls, flood gates, dams, diversion channels, storm drain systems) as well as the natural rivers corridors, subsidence, settlement & consolidation, and hydrologic hazards (rain storms, snow melt) that inundate low lying areas and floodplains;
- Power Supply – Elements of the electrical power grid that supply electricity to agricultural, commercial/industrial, government and the public; and
- Ecosystem – Physical and biological components of the environment. Physical attributes include habitat areas, soil substrates, water supply and quality. Biological considerations include flora and fauna.

The California Sacramento Delta 3ICIS is a very complex highly interactive 'legacy' system embedded in similarly complex natural environmental and social - political systems. It is of critical importance directly for the population and environment of the State of California and indirectly for the rest of the United States.

The goals of this research project are to develop the following Quality Management Assessment System Process (QMAS):

1. System Definition and Conceptualization
2. Domain Expert / Key Informant Assessment Team Identification and Formation
3. Identification of the key vulnerabilities or chokepoints (aka Factors of Concern)
4. Failure Scenario Development
5. Detailed Qualitative and Quantitative Risk Assessment and Management that accounts for 3ICIS spatial variability, temporal variability (historical, current, future), and non-linearity (SYRAS++)

This research will answer the following fundamental questions:

1. What are the major drivers that threaten Resilience & Sustainability (current, future)?
2. What is the current Resilience & Sustainability state of the 3ICIS?
3. What future Resiliency & Sustainability states are expected given the status quo persists?
4. What are the potential consequences/impacts associated with future Resiliency & Sustainability states given the status quo persists?
5. What adaptation and mitigation strategies can be employed to create an "acceptable" Resilient & Sustainable 3ICIS?

2008 Midwest Levee Failure Investigation: Dr. Storesund was the lead researcher for this National Science Foundation sponsored collaborative research investigation between UC Berkeley, Texas A&M University, and the Missouri University of Science and Technology. The research was an immediate effort to collect sensitive and time-dependent perishable data will comprehensively characterize select levee failure locations to provide essential levee characterization and performance data for use in subsequent numerical analyses. The levee characterization consisted of:

1. An initial field reconnaissance to visit known breach sites along the Mississippi River between St. Louis, MO and Davenport, IA to document (via photographs) site conditions, collect eyewitness accounts, and develop a list for detailed site-specific analyses;

2. Conducting high-detail laser imaging survey (Terrestrial LiDAR) of breach and erosion/scour features in the levees. These surveys will be used to validate future numerical simulations that predict the final scour/erosion profile for specified overtopping conditions;

3. Characterization of the vegetative/grass cover on the earthen levee side slopes to determine erosion-resistance provided. This levee characteristic is frequently omitted from field characterization studies, yet is very important in the performance of the levee during overtopping conditions;

4. Characterization of the levee soil materials, including the United States Soil Classification (USCS) soil types, plasticity (Atterberg Limits), grain size distribution (sieve sizes), in-situ density, maximum dry density, Erosion Function Apparatus (EFA) erodibility characterization and jet erosion testing; and

5. Documentation of the river stage at the location of the levee failure based on eyewitness accounts as well as available USGS Stream Gage Data. This data is essential to correctly evaluate overtopping depths and durations and associated water velocities on the 'protected side' of the flood protection levee.

The sites investigated include: Brevator (Missouri); Winfield (MO); Cap au Gris (MO); Kings Lake (MO); Norton Woods (MO); Kickapoo (MO); Bryants Creek (MO); Indian Graves (IL); Two Rivers (IA).

2019 Brumadinho Dam Collapse, Brazil: Dr. Storesund has been collecting background data and performing desktop studies based on available information with regards to this catastrophic tailings dam failure in January 2019. The dam breach resulted in the tragic deaths of more than 150 individuals. His studies examine the intersection of uncertainties in engineering analyses, regulatory compliance, and deviation between the believed factor of safety vs actual factor of safety.

2015 Fundao Tailings Dam Collapse, Brazil: Dr. Storesund has been collecting background data and performing desktop studies based on available information with regards to this catastrophic tailings dam failure in January 2019. The dam breach resulted in the tragic deaths of more than 150 individuals. His studies examine the intersection of uncertainties in engineering analyses, regulatory compliance, and deviation between the believed factor of safety vs actual factor of safety.

Mosaic Uncle Sam Tailing Pond, Convent, Louisiana: Dr. Storesund is providing risk management consultations on this gypsum tailings dam experiencing excessive movements.

National River Restoration Science Synthesis: The National River Restoration Science Synthesis (NRRSS) was a nation-wide effort to characterize the practice of river restoration. It consisted of three phases: synthesis of national and state restoration databases, phone surveys with select river restoration practitioners, and detailed river restoration post-project appraisals within California. Dr. Storesund was active, under the direction of Dr. G. M. Kondolf, and participated in the completion of 40 post project appraisals (PPA) of California river restoration projects. The PPA evaluations consisted of watershed delineations, hydraulic and hydrology characteristics determinations, review of planning and design approaches, review of permit applications, field surveys and performance assessments, and engineering documentation of post-construction performance.

Projects evaluated:

Ackerman Creek Restoration Project	Alameda Creek (Niles Dam Removal)
Alameda Creek (Sunol Dam Removal)	Alamo Creek (Main Branch)
Alamo Creek (East Branch) Project	Arroyo de la Laguna Bank Stabilization
Arroyo Mocho	Arroyo Viejo Creek Restoration
Baxter Creek (Booker T. Anderson)	Baxter Creek (Gateway)
Baxter Creek (Pointsett Park)	Bear Creek Restoration Project
Blackberry Creek (Thousand Oaks)	Brandy Creek (A-Frame Dam Removal)
Carmel River at deDampierre	Carmel River at Schulte Road
Castro Valley Creek Restoration	Cerrito Creek (El Cerrito Plaza)
Chorro Flats Enhancement Project	Clarks Creek
Clear Creek (McCormic Dam Removal)	Cold Creek
Crocker Creek Dam Removal	Cuneo Creek Restoration
Green Valley Creek	Lower Guadalupe River Reach B
Lower Ritchie Creek Dam Removal	Lower Silver Creek Reach I
Martin Canyon Creek	Miller Creek
Redwood Creek	Sausal Creek Restoration Project
Strawberry Creek	Tassajara Creek
Tennessee Hollow (Thompson Reach)	Uvas Creek Restoration
Village Creek (UC Berkeley)	Wildcat Creek at Alvarado Park
Wildcat Creek Flood Control Channel	Wilder Creek Restoration Project

More information on the NRRSS study and these specific PPA evaluations can be found at http://landscape.ced.berkeley.edu/~kondolf/NRRSS/.

PROFESSIONAL AFFILIATIONS:

ASCE Leadership and Management Committee
Chair 2010 - 2012
Corresponding Member 2003 – 2009
ASCE Region 9 Governor (San Francisco Section), 2019 - 2022
ASCE San Francisco Section
Past President 2012-2013
President 2011-2012
President Elect 2010-2011
Vice President 2009 - 2010
American Society of Civil Engineers: San Francisco Section YMF President 2003-2004
ASCE San Francisco Section Water Resources Group
Director 2009 -2011
ASCE San Francisco Section Geotechnical Society Steering Committee
ASCE San Francisco Section Infrastructure Report Card Committee
ASCE GEO-Institute
National Academy of Forensic Engineers
National Society of Professional Engineers
California Society of Professional Engineers
UC Berkeley Geotechnical Engineering Society
UC Berkeley Engineering Alumni Society

AWARDS:

Eagle Scout, Troop 27, Eureka, California (1992)

Outstanding YMF Civil Engineer (2004) San Francisco Section ASCE

Outstanding YMF Civil Engineer in the Private Sector (2008) Western Regional Younger Member Council, ASCE

Outstanding ASCE Younger Member Forum Officer, ASCE Region 9 (2009)

President's Award, San Francisco Section ASCE (2012)

H.J. Brunnier Award, San Francisco Section ASCE (2013)

ASCE Edmund Friedman Young Engineer Award for Professional Achievement (2013)

APPENDIX B

List of Cases

Legal Case Consultations Summary - Dr. Rune Storesund

Case	Role	Year	Report	Deposition	Court Testimony
Erosion and Scour Analyses, Mississippi River Gulf Outlet, St. Bernard Parish, Louisiana	Support	2008	Yes	No	No
Armando P. Vanni et al, vs Rindge Land Reclamation District et al. Case No. CV025820, Superior Court of the State of California, County of San Joaquin	Support	2011	No	Yes (2011)	Yes (2011)
KATRINA CANAL BREACHES CONSOLIDATED LITIGATION, UNITED STATES DISTRICT COURT EASTERN DISTRICT OF LOUISIANA, CIVIL ACTION NO. 05-4182 SECTION "K"	Support	2012	No	No	No
PNG-LNG Landslide Investigation (EXXON; Papua New Guinea)	Expert	2012	No	No	No
PSZONKA, WARD, REGELBRUGGE et al, vs STATE OF WASHINGTON; GRANDY LAKE FOREST ASSOCIATES, LLC, a Washington Limited Liability Company; and SNOHOMISH COUNTY, SUPERIOR COURT OF THE STATE OF WASHINGTON COUNTY OF KING, No. 14-2-18401-8 SEA	Expert	2016	Yes	Yes (2016)	N/A
Hynes v. Menaged, Superior Court California-Napa County, 26-61456, 2017	Expert	2017	No	No	Yes (2017)
Sewell et al v SWB, Civil District Court for the Parish of Orleans, State of Louisiana, 15-4501	Expert	2017	Yes	Yes (2017)	Yes (2018)
State of California v. Rodney Doyle Edmiston, Superior Court of California, County of Santa Clara, Docket No. C1761717	Expert	2017	No	No	N/A
Union Point Marina Bar and Grill Inc. and Brake Properties, LLC, vs State of California, Department of Transportation. Case No. STK-CV-UED-2014-0007625	Support	2018	No	No	No
Sewell et al v SWB - Trial Group B, Civil District Court for the Parish of Orleans, State of Louisiana, 15-4501	Expert	2018	Yes	No	Yes (2018)
Alford, et al. V. EBMUD, et al. Contra Costa Superior Court Case No. C16-01348	Support	2018	No	N/A	N/A
M. Langenstein & Sons, Inc., et al, v Sewerage and Water Board of New Orleans, Consolidated with K&B Louisiana Corporation dba Rite Aid Corporation vs Sewerage and Water Board, Civil District Court of the Parish of Orleans, State of Louisiana, Division "D" No. 15-11971 c/w 15-11394	Expert	2018	Yes	No	N/A
Sewell et al v SWB - Trial Group D, Civil District Court for the Parish of Orleans, State of Louisiana, 15-4501	Expert	2019	Yes	No	Yes (2019)
Lowenburg et al v SWB, Civil District Court for the Parish of Orleans, State of Louisiana, 2016-621	Expert	2019	Yes	No	Yes (2019)
THE PRESERVE AT REDWOOD SHORES OWNERS ASSOCIATION, a California nonprofit mutual benefit corporation vs. KB HOME SOUTH BAY, INC., a California Corporation	Support	2019	No	Yes (2019)	N/A
Walker v. Tran, Alameda County Superior Court, Case No. HG18891110	Expert	2019	No	Yes (2019)	N/A
West Sacramento Area Flood Control Agency (WSAFCA) v AECOM, Southport Levee Improvement Project.	Support	2019	Yes	No	No
Tara Shaw v. Privilege Underwriters Reciprocal Exchange, Tassin Pile & Foundation LLP, Foundation Materials, Inc., Sun Custom, LLC, ABC Insurance Company, QRS Insurance Company, XYZ Insurance Company, and Matthew S. French, No. 17-11511, Civ. Dist. Court for the Parish of Orleans, Louisiana, Div. D.	Expert	2019	Yes (2019)	Yes (2020)	Potentially (2022)
Pacific Gas and Electric Company v. California Department of Water Resources, Superior Court of the State of California, County of Butte, Case No. 18CV02014	Expert	2019	Yes (2021)	Yes (2021)	Potentially (2022)
Vittimberga Landslide Litigation (Orinda, CA)	Support	2020	No	No	No
Tappan Terrace Landslide Litigation (Orinda, CA)	Support	2020	No	No	No
Bear Creek Road Landslide Litigation (Boulder Creek, CA)	Support	2020	No	No	No
Zanotti Residence Landslide Litigation (Cupertino, CA)	Support	2020	No	No	No
Sleazak Residence Landslide Litigation (San Pablo, CA)	Support	2020	No	No	No
Archer Residence Litiation (Orinda, CA)	Support	2020	No	No	No
CITY OF ISSAQUAH, a municipal corporation, vs. ORA TALUS 90, LLC, and RESMARK EQUITY PARTNERS, LLC, ORA TALUS 90, LLC, and RESMARK EQUITY PARTNERS, LLC, Third-Party Plaintiffs, vs. TERRA TALUS LLC, ELEMENT RESIDENTIAL INC., JOSHUA FREED, J.R. HAYES & SONS; United States District Court, Western District of Washington at Seattle. No. 18-cv-00910-RSM.	Expert	2020	Yes	Yes (2021)	Potentially (2022)
KENNETH RIDOUT AND ERICA RIDOUT, vs. HEDGEROW, LLC, OWEN H. BENSON, 3 S MANAGEMENT SERVICES, LLC, PACIFIC EDGE MANAGEMENT, LLC, URBAN EDGE DEVELOPMENT, LLC, BPCI EARTHWORKS, LLC, and THE RILEY GROUP, INC., ; King County, State of Washington, CASE #: 19-2-3107 4-0 SEA	Expert	2021	N/A	N/A	N/A